Hutchinson
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Phosphorus Budget Tool in Support of Sustainable Development for the Lake Simcoe Watershed

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Prepared For: **Ontario Ministry of the Environment**

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Executive Summary

Lake Simcoe is enriched by nutrients from land use activities in its watershed and has, for many years, been the focus of efforts to protect and restore its water quality. The *Lake Simcoe Protection Act* (LSPA) was passed by the Ontario legislature in 2008 and required establishment of the Lake Simcoe Protection Plan (LSPP). The LSPP was approved in 2009 and included a series of policies that were to be implemented to restore water quality and other ecological attributes of the lake. This document is prepared in response to Policy 4.8e of the LSPP, which states that:

> *"An application for major development shall be accompanied by a stormwater management plan that demonstrates...*
>
> > *e. through an evaluation of anticipated changes in phosphorus loadings between pre-development and post-development, how the loadings shall be minimized."*

The intent of Policy 4.8e is that plans for new development in the Lake Simcoe watershed adopt Best Management Practices (BMPs), Low Impact Development (LID) techniques and innovative stormwater management techniques to achieve sustainable development practices that will reduce the phosphorus loading from new urban development. In practice, Policy 4.8e is interpreted as a requirement that post development loadings be reduced from pre-development loadings on any major development site, in order to achieve overall reductions in loadings to the lake. This interpretation is in line with Strategic Direction #3 in the Phosphorus Reduction Strategy, which requires a move to "no net increase" of phosphorus for new development in the Lake Simcoe watershed.

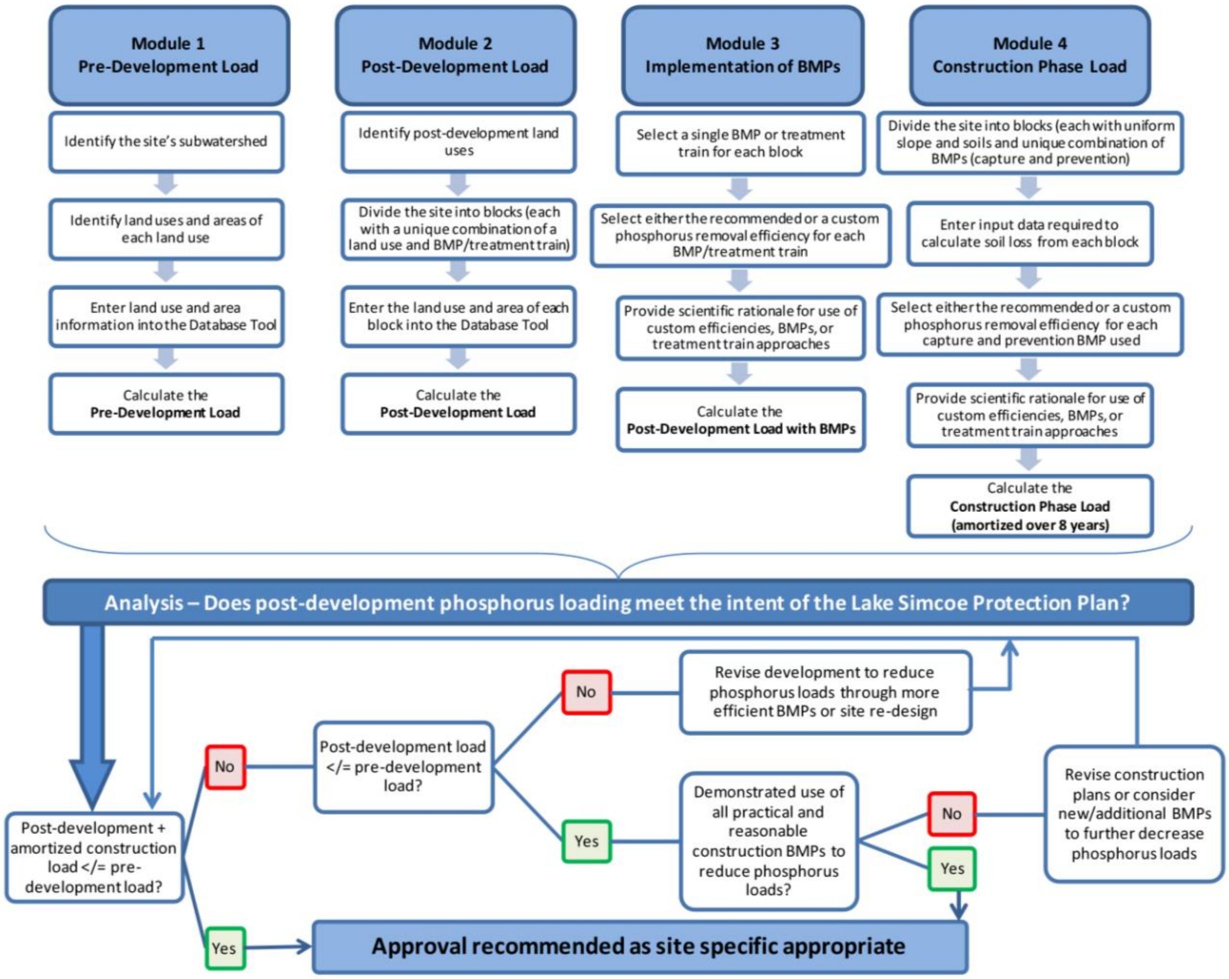
Policy 4.8e requires standardized methods to estimate and compare pre- and post-development phosphorus loadings with implementation of BMPs and LID techniques. In addition, the Ontario Ministry of the Environment (MOE) is recommending that municipalities require phosphorus loading from the construction phase of new development be minimized in support of other related designated policies in the LSPP, (i.e., 4.20 and 'have regard' for policy 4.21), with the objective that "post-development load + construction load" be less than "pre-development load".

The MOE retained Hutchinson Environmental Sciences Ltd. (HESL), Greenland International Consulting Ltd. and Stoneleigh Associates to develop the *Phosphorus Budget Guidance Tool to Guide New Development in the Lake Simcoe Watershed*. This "Tool" provides a transparent, technically sound approach to estimate phosphorus loading from stormwater runoff in the pre-, post- and construction phases of new development in the Lake Simcoe watershed. The Tool does not address atmospheric sources of phosphorus in dust generated from land use practices, as the science is not yet advanced to the point where estimates can be made. It does account for atmospheric deposition of phosphorus to open water and atmospheric deposition to land surfaces is included in the export coefficients for various land use practices.

The Tool couples an "Export Coefficient Modelling" approach with BMPs for stormwater management in the post-development and construction phases. It uses estimates of phosphorus export that were developed for specific land uses using the most recent and site specific estimates available. These are coupled to standard estimates of phosphorus reduction efficiencies for BMPs and LID techniques for stormwater management that were summarized

from an extensive review of case studies and technical literature to estimate post-development phosphorus load after mitigation. Construction phase loadings are derived as a function of the area of land that is exposed during construction and soil loss, with adjustments for use of BMPs. These calculations and export coefficients are coded into four separate modules that consider sediment and nutrient loss, as summarized in Figure 1 of the report and reproduced below.

Figure 1. Schematic of modular approach to phosphorus guidance.



Module 1 Estimates pre-development phosphorus loads for standardized, subwatershed-specific land uses contained within the study site immediately prior to development. The guidance is, for the most part, specific to each subwatershed, in recognition that the Lake Simcoe watershed is made up of different subwatersheds and that export from each will vary in response to precipitation patterns, soils and slope. Land use categories are derived from those used in Berger (2010), as shown in Table 2 of the report and reproduced below. Subwatershed-specific export coefficients were developed for individual land uses using Berger (2010) as the basis, but were modified to address unexplained variance in export between land uses and subwatersheds in the Lake Simcoe basin.

Table 2. Land-Use Specific Phosphorus Export Coefficients (kg/ha/yr) for Lake Simcoe Subwatersheds

Subwatershed	Phosphorus Export (kg/ha/yr)											
	Cropland	Hay-Pasture	Sod Farm/Golf Course	High Intensity Development		Low Intensity Development	Quarry	Unpaved Road	Forest	Transition	Wetland	Open Water
				Commercial /Industrial	Residential							
Monitored Subwatersheds												
Beaver River	0.22	0.04	0.01	1.82	1.32	0.19	0.06	0.83	0.02	0.04	0.02	0.26
Black River	0.23	0.08	0.02	1.82	1.32	0.17	0.15	0.83	0.05	0.06	0.04	0.26
East Holland River	0.36	0.12	0.24	1.82	1.32	0.13	0.08	0.83	0.10	0.16	0.10	0.26
Hawkestone Creek	0.19	0.10	0.06	1.82	1.32	0.09	0.10	0.83	0.03	0.04	0.03	0.26
Lovers Creek	0.16	0.07	0.17	1.82	1.32	0.07	0.06	0.83	0.06	0.06	0.05	0.26
Pefferlaw/Uxbridge Brook	0.11	0.06	0.02	1.82	1.32	0.13	0.04	0.83	0.03	0.04	0.04	0.26
Whites Creek	0.23	0.10	0.42	1.82	1.32	0.15	0.08	0.83	0.10	0.11	0.09	0.26
Unmonitored Subwatersheds												
Barrie Creeks	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
GeorginaCreeks	0.36	0.12	0.24	1.82	1.32	0.13	0.08	0.83	0.10	0.16	0.10	0.26
Hewitts Creek	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Innisfil Creeks	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Maskinonge River	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Oro Creeks North	0.36	0.12	0.24	1.82	1.32	0.13	0.08	0.83	0.10	0.16	0.10	0.26
Oro Creeks South	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Ramara Creeks	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Talbot/Upper Talbot River	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
West Holland River	0.36	0.12	0.24	1.82	1.32	0.13	0.08	0.83	0.10	0.16	0.10	0.26

Module 2 – Estimates post-development phosphorus loads that are representative of the proposed changes in land use for the study site using the same data sources used in Module 1, but accounting for the change in land use that will occur with development.

Module 3 – Estimates efficiencies attributed to classes of BMPs that can be used to reduce stormwater phosphorus loads in the post-development scenario. These efficiencies are based on data that is sourced from relevant, regional studies. The Tool provides standardized phosphorus reduction efficiencies (with rationale) for specific BMPs, but also allows the user to enter their own efficiencies provided that the rationale is also documented and is acceptable to the MOE. The Tool also allows the user to use custom BMPs or to enter the net efficiency achieved using a Treatment Train approach, which would also require documentation in a rationale that is acceptable to the MOE. The BMP selection criteria and efficiencies are shown below as reproduced from Figure 5 and Table 3 of the report, as follows:

Figure 5. Decision tree for selecting appropriate phosphorus removal efficiencies for stormwater and construction BMPs.

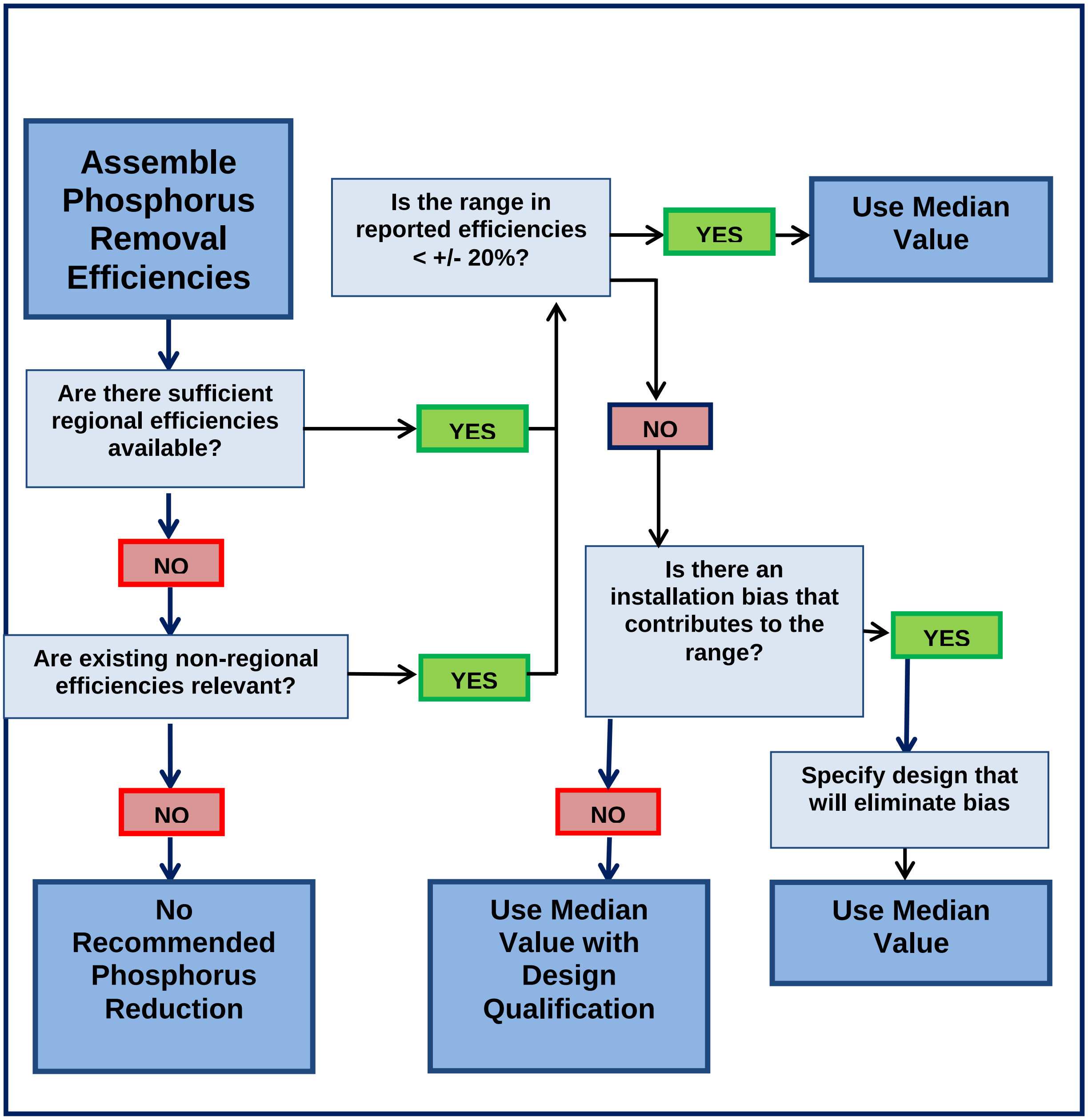


Table 3. Phosphorus Removal Efficiencies for Major Classes of BMPs Using the Decision Tree (Figure 5).

BMP Class	Reference IDs[1]	Reported Phosphorus Removal Efficiency (%)		Relevant to Ontario?	Range <40%?	Are Non-Ontario values acceptable?	Possible design criteria?	Median % Removal Efficiency
		Min	Max					
Post-development BMPs								
Bioretention Systems	8-10, 12,13, 34-38, 40	-1552	80	no	no	no	No	none
Constructed Wetlands	104, 106, 109	72	87	yes	yes			77
Dry Detention Ponds	104, 109	0	20	no	yes	yes		10
Dry Swales	24, 26-32	-216	94	no	no	no	possible	none
Enhanced Grass/Water Quality Swales	21, 104	34	55	no	yes	no	No	none
Flow Balancing Systems	106	77		no	?	yes	Min data	77
Green Roofs	2	-248		no	no	no	No	none
Hydrodynamic Devices	109	-8		no	?	yes		none
Perforated Pipe Infiltration/Exfiltration Systems	7, 4	81	93	yes	yes			87
Sand or Media Filters	104, 109	30	59	no	yes	yes		45
Soakaways - Infiltration Trenches	6, 104	50	70	no	yes	yes		60
Sorbtive Media Interceptors	111	78	80	no	yes	yes		79
Underground Storage	106	25		no	?	yes	Min data	25
Vegetated Filter Strips/Stream Buffers	6, 42, 104	60	70	no	yes	yes	Yes	65
Wet Detention Ponds	104-106, 109	42	85	yes	yes			63

Notes: [1]References associated with IDs are provided in Appendix 7.

Module 4 – Examines the potential for erosion and sediment loss during the construction phase on the basis of the Universal Soil Loss Equation and provides guidance to the user on appropriate BMPs that can be implemented during this phase to minimize sediment loss and resultant phosphorus export. The module calculates loads for the entire construction phase, but pro-rates this one-time load to annual loads to account for the eight-year hydraulic residence time in Lake Simcoe. The quantification of expected soil and phosphorus loss from a construction site is an uncertain process, even under ideal conditions. Determining expected loss reductions from the use of various on-site BMPs adds to the uncertainty. Even with

inherent uncertainty, however, the Guidance proceeds from the principle that the process of quantifying soil and nutrient losses as part of the planning and approval process will have a beneficial impact on water quality regardless of whether the estimated loads are actually realized, as long as the appropriate BMPs are selected and properly implemented in a manner that minimizes soil and phosphorus losses from the site. The process of estimating construction phase loadings and the means to minimize them is one of awareness that can be translated into the site development process.

The guidance is based on information that is normally required of the proponent as part of the standard process of planning approvals. Pre- and post-development land uses are derived from the Environmental Impact Statement (EIS) prepared by the proponent and BMPs for stormwater management would be developed and described in the Stormwater Management Plan for the new development that is prepared in support of the application. The proponent uses these materials as input to the Database Tool to calculate loadings in a standard format by the approved process.

The Database Tool calculates resulting loads from each of the four modules and determines the net impact in terms of the phosphorus budget associated with the proposed development site. The analysis distinguishes permanent changes in phosphorus load resulting from changes in land use (i.e., pre- vs. post-development) from temporary loadings from construction.

To meet the intent of Policy 4.8e to minimize phosphorus loadings to Lake Simcoe from development, the MOE will recommend that municipalities approve development as site specific appropriate if:

a) Post-development load < or = pre-development load, and

b) (Post-development + amortized construction phase) load < or = pre-development loading,

OR

If (Post-development + amortized construction phase) load > pre-development loading,

THAT

All reasonable and feasible construction phase BMPs have been identified for implementation, documented and accounted for in the application.

The Tool consists of three elements:

1. A **Technical Guidance Manual** that provides the reference material used in developing the Tool, the rationale for the development of the Tool, and implementation guidance in line with Policy 4.8e of the LSPP,

2. A **Microsoft ACCESS© Database Tool** that facilitates the calculation of a phosphorus budget for new development in accordance with the technical guidance, and

3. A **Database User's Manual** explaining the operation of the database.

The "*Phosphorus Budget Guidance Tool to Guide New Development in the Lake Simcoe Watershed"* is intended for use by the development community, municipalities, the MOE and the Lake Simcoe Region Conservation Authority to facilitate review of new development applications for their compliance with Policy 4.8e of the Lake Simcoe Protection Plan. It

includes a simplified checklist of required elements of any submissions made for the use of reviewers.

Table of Contents

List of Figures

List of Tables

Appendices

1. Introduction

Lake Simcoe is enriched by nutrients from land use activities in its watershed and has, for many years, been the focus of efforts to protect and restore its water quality. These efforts began with the Lake Simcoe Environmental Strategy in the mid 1980s and led to passage of the *Lake Simcoe Protection Act* (LSPA) by the Ontario legislature in 2008. The *Act* required the establishment of the Lake Simcoe Protection Plan (LSPP) to regulate inputs of nutrients (specifically phosphorus) to Lake Simcoe. The LSPP was approved in 2009 and included a series of policies that were to be implemented to restore water quality and other ecological attributes of the lake.

This document addresses implementation of Policy 4.8e of the LSPP, which states that:

> *"An application for major development shall be accompanied by a stormwater management plan that demonstrates...*
>
> > *e. through an evaluation of anticipated changes in phosphorus loadings between pre-development and post-development, how the loadings shall be minimized."*

This direction by the MOE recognizes that, although the LSPP requires reductions in phosphorus loading, the Lake Simcoe watershed is the focus of substantial planned population growth in the next 20 years. Population growth brings the potential for additional phosphorus loading that can only be managed or reduced through: a) innovative wastewater treatment at advanced wastewater treatment plants (which is addressed through other elements of the LSPP), and b) innovations in stormwater management that would allow development to proceed without increasing phosphorus loads to the lake.

The intent of Policy 4.8e is that new development in the Lake Simcoe watershed adopts Best Management Practices (BMPs), Low Impact Development (LID) techniques and innovative stormwater management techniques to achieve sustainable development practices that will reduce the phosphorus loading from new urban development. In practice, Policy 4.8e is interpreted as a requirement that post-development loadings be reduced from pre-development loadings on any major development site, in order to achieve overall reductions in loadings to Lake Simcoe. This interpretation is in line with Strategic Direction #3 in the Phosphorus Reduction Strategy, which requires a move to "no net increase" of phosphorus for new development in the Lake Simcoe watershed.

Implementation of Policy 4.8e requires a method to quantify and compare pre- and post-development phosphorus loadings and an elaboration of BMP/LID methods that can minimize loading from new development. The guidance must be site-specific, in recognition that phosphorus export will vary in response to differing precipitation patterns, soils and slopes that occur across the Lake Simcoe watershed. In addition, the MOE recognizes that phosphorus loading during the construction phase of development needs to be considered, as construction is an ongoing process in the watershed that contributes non-point source phosphorus loads to the lake. The phasing of construction projects means that this loading can occur over an extended period of time. The loading itself, however, is temporary, and the construction load from each development will be assimilated within Lake Simcoe over time, with no long-term change to the phosphorus status of the lake.

The MOE retained Hutchinson Environmental Sciences Ltd. (HESL), Greenland International Consulting Ltd. and Stoneleigh Associates to develop the *"Phosphorus Budget Guidance Tool to Guide New Development in the Lake Simcoe Watershed"* (the "Tool"). The Tool provides a transparent, science-based and consistent approach to estimate phosphorus loadings from stormwater runoff[1] in the pre-, post- and construction phases of new development in the Lake Simcoe watershed, which can be utilized by the development community, municipalities, the MOE and the Lake Simcoe Region Conservation Authority (LSRCA). The Tool consists of three elements:

1. A **Technical Guidance Manual** that provides the reference material used in developing the Tool, the rationale for the development of the Tool, and implementation guidance in line with Policy 4.8e of the LSPP,

2. A **Microsoft ACCESS© Database Tool** that facilitates the calculation of a phosphorus budget for new development in accordance with the technical guidance, and

3. A **Database User's Manual** explaining the operation of the database.

2. Tool Development Considerations

Development of the Tool was guided by the MOE objective to:

> *"Provide the development community and municipalities with a consistent approach to estimating phosphorus loadings for pre- and post-development and the construction phase of development in the Lake Simcoe watershed that considers subwatershed characteristics."*

The intent of this objective is to support sustainable development while continuing to reduce the impact of phosphorus on Lake Simcoe by demonstrating through *"...an evaluation of anticipated changes in phosphorus loadings between pre-development and post-development, how the loadings shall be minimized"* in keeping with Policy 4.8e of the LSPP. Several key factors were considered in the development of the Tool to meet the objective.

The first is that the development of Low Impact Development (LID) techniques is a relatively new field and, as such, many techniques are innovative and new techniques will be developed over time. Although a BMP/LID technique may be worthwhile and effective, documented case studies that verify its performance with measured data may not be readily available. The Tool is based on proven techniques, as demonstrated through documented effectiveness, but must also accommodate innovation as it occurs. It cannot anticipate these innovations, but must be able to accommodate them by setting criteria and standards for their use.

The second is the complexity of monitoring storm water runoff to obtain the necessary data to estimate phosphorus load. The hydrologic response is highly variable and depends on

[1] *The Tool does not address atmospheric sources of phosphorus in dust generated from land use practices, as the science is not yet advanced to the point where estimates can be made. It does account for atmospheric deposition of phosphorus to open water and atmospheric deposition to land surfaces is included in the export coefficients for various land use practices.*

antecedent soil moisture, storm intensity and duration, site topography and soils and a host of factors that are site specific and therefore difficult to extrapolate to a variety of development sites. There is also variance in pollutant delivery to receiving water, which varies with the elapsed time since the previous storm and the stage of the hydrograph sampled (first flush vs. later storm stages). This complexity needs to be managed so that reasonable and reliable estimates can be used by all practitioners of the policy without the need for lengthy site-specific monitoring or detailed modelling. The intent is to develop a screening level tool.

Third, any Tool needs to find a balance of methods between site specific monitoring, modelling, or the use of reliable estimates from a database of previous studies. The ideal situation would be one in which phosphorus load was measured for a specific site in the pre-development stage and again in the post-development stage. This approach is impractical, however, because a) monitoring after development is too late to inform the decision of whether or not to develop the site, b) monitoring-based approaches do not allow assessment of a variety of BMPs, and c) many development sites are small and have no surface water drainage systems that would allow monitoring of runoff. A monitoring-based approach would require a long-term monitoring period that incorporated climatic variance and this is clearly not feasible for most applications. Model-based approaches, by contrast, have the advantage of allowing estimates of the current condition, future conditions, and the effectiveness of BMPs. Accurate estimates of these can be incorporated into models and usefully applied if the models incorporate the range of necessary factors and have been validated against good measured data.

Finally, the Tool must provide an approach that is:

- workable – allows practitioners and reviewers to complete or review the necessary phosphorus budgets without the need for undue additional expense or access to sophisticated software or modelling capabilities,
- timely - produces the required analysis within a reasonable time frame to allow for timely review and approvals.
- defensible – robust and providing reliable estimates that can stand up to review, and
- adaptable – such that new BMP/LID techniques or better estimates of phosphorus export can be used as they become available.

3. Technical Guidance Manual

3.1 Overview

The guidance is intended to complement and take advantage of the routine municipal planning process for new development, as it uses much of the same information on site conditions and proposed storm water management considerations. The guidance assists the user by providing adequate technical detail for inclusion in a submission to a municipality for development approval. It is, however, assumed that the user has some level of technical or engineering knowledge of soil erosion, nutrient loss processes and storm water management techniques. Some detailed ecological knowledge is valuable to assist with land use classifications.

The Technical Guidance Manual and Database Tool are divided into four modules that consider sediment and nutrient loss as follows:

- **Module 1** – Estimates pre-development phosphorus loads for representative, sub catchment level land uses contained within the study site,
- **Module 2** – Estimates post-development phosphorus loads that are representative of the proposed land uses for the study site without BMPs to reduce phosphorus loads,
- **Module 3** – Estimates effectiveness of proposed BMPs in reducing phosphorus loads in the post-development scenario, and
- **Module 4** – Examines the potential for erosion and sediment loss during the construction phase, provides guidance to the user on appropriate BMPs that can be implemented during this phase to minimize sediment loss and resultant phosphorus export and estimates sediment and phosphorus loss from the site for each phase of the construction process.

Once each of the four modules is completed by entering information into the Database Tool, the results are subjected to a comparative analysis between pre- and post-development phosphorus loads and with loads generated by construction activities. Decision rules are then applied to the comparative analysis to determine if phosphorus loads are reduced relative to existing conditions to meet the intentions of the LSPP Policy 4.8e and to support approval of the development application. The MOE will recommend that municipalities approve development as site specific appropriate if:

a) Post-development load < or = pre-development load, and

b) (Post-development + amortized construction phase) load < or = pre-development loading,

   OR

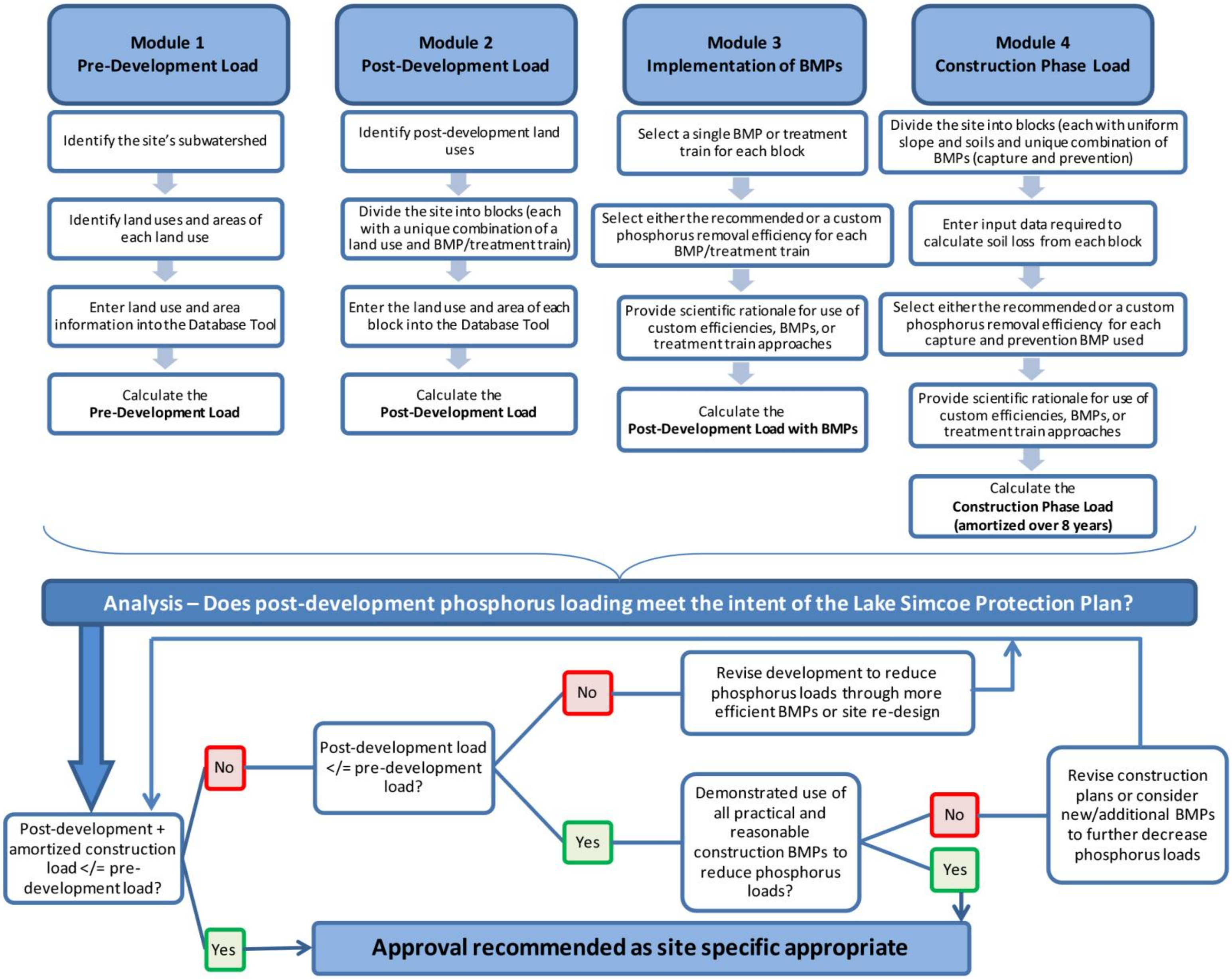
   If (Post-development + amortized construction phase) load > pre-development loading,

   THAT

   All reasonable and feasible construction phase BMPs have been identified for implementation, documented and accounted for in the application.

The modular approach to completing a phosphorus budget using the Tool is illustrated in Figure 1. Technical guidance for each module including the approach, rationale for that approach and step-by-step instructions to complete the modules is provided in the following sections.

Figure 1. Schematic of modular approach to phosphorus guidance.



3.2 Modules 1 and 2: Pre- and Post-Development Phosphorus Load Estimation

3.2.1 Approach

An export coefficient approach is used to estimate non-point source phosphorus loadings for pre-development (Module 1) and post-development (Module 2) phases.

The export coefficient approach was developed in North America to predict nutrient inputs to lakes and streams (Dillon and Kirchner, 1975; Beaulac and Reckhow, 1982; Rast and Lee, 1983) and is now a well-established method of estimating phosphorus export when measured tributary flows and total phosphorus concentration data are lacking (e.g., Dillon *et al.* 1986, Johnes 1996, Winter and Duthie 2000, Paterson et al., 2006). The export coefficient approach is also used where it is desirable to forecast nutrient export from a land area prior to a change in land use or prior to implementing Best Management Practices, in which case it is used as a predictive tool.

The use of phosphorus export coefficients for estimating phosphorus loading is based on the knowledge that specific land forms and land uses yield or export known quantities of phosphorus over an annual cycle. Knowing the area of land in a watershed devoted to specific uses and the quantities of nutrients exported per unit area of these uses (nutrient export coefficients), annual phosphorus loading can be calculated as:

$$L = \Sigma\, EiAi,$$

where L is the total phosphorus load from a given area of land (e.g., development site), Ei is the export coefficient selected for a specific land use and Ai is the area of that land use.

A working group that included scientists from HESL, Greenland and the MOE was formed to select appropriate phosphorus export coefficients for different land uses that are applicable to the Lake Simcoe subwatersheds and that were developed and/or validated using recent measured data. The selected export coefficients were derived from 1) the results of CANWET™ modeling by The Louis Berger Group Inc. (Berger, 2010), 2) results of monitoring under the Stormwater Assessment Monitoring and Performance Program of MOE (SWAMP, 2005) and 3) analysis, review and refinement by the study team.

The Berger (2010) report used the CANWET™ model to estimate phosphorus load (in kg/yr) for land uses that are specific to each of the subwatersheds in the Lake Simcoe basin. The SWAMP studies provide recent measured total phosphorus export for urban land uses: commercial, industrial and residential development areas in southern Ontario, which were used by the MOE in the development of a phosphorus budget for Lake Simcoe under the Lake Simcoe Environmental Management Strategy (LSEMS; Scott et al., 2006, Winter et al., 2002 and 2007). A description of each of the land use classes is provided in Table 1. The final land-use specific export coefficients for the 19 Lake Simcoe subwatersheds (see Figure 2) are provided in Table 2. Details of the derivation of the export coefficients are provided in Section 3.2.1.1.

Figure 2. Lake Simcoe subwatersheds (from Berger (2010).

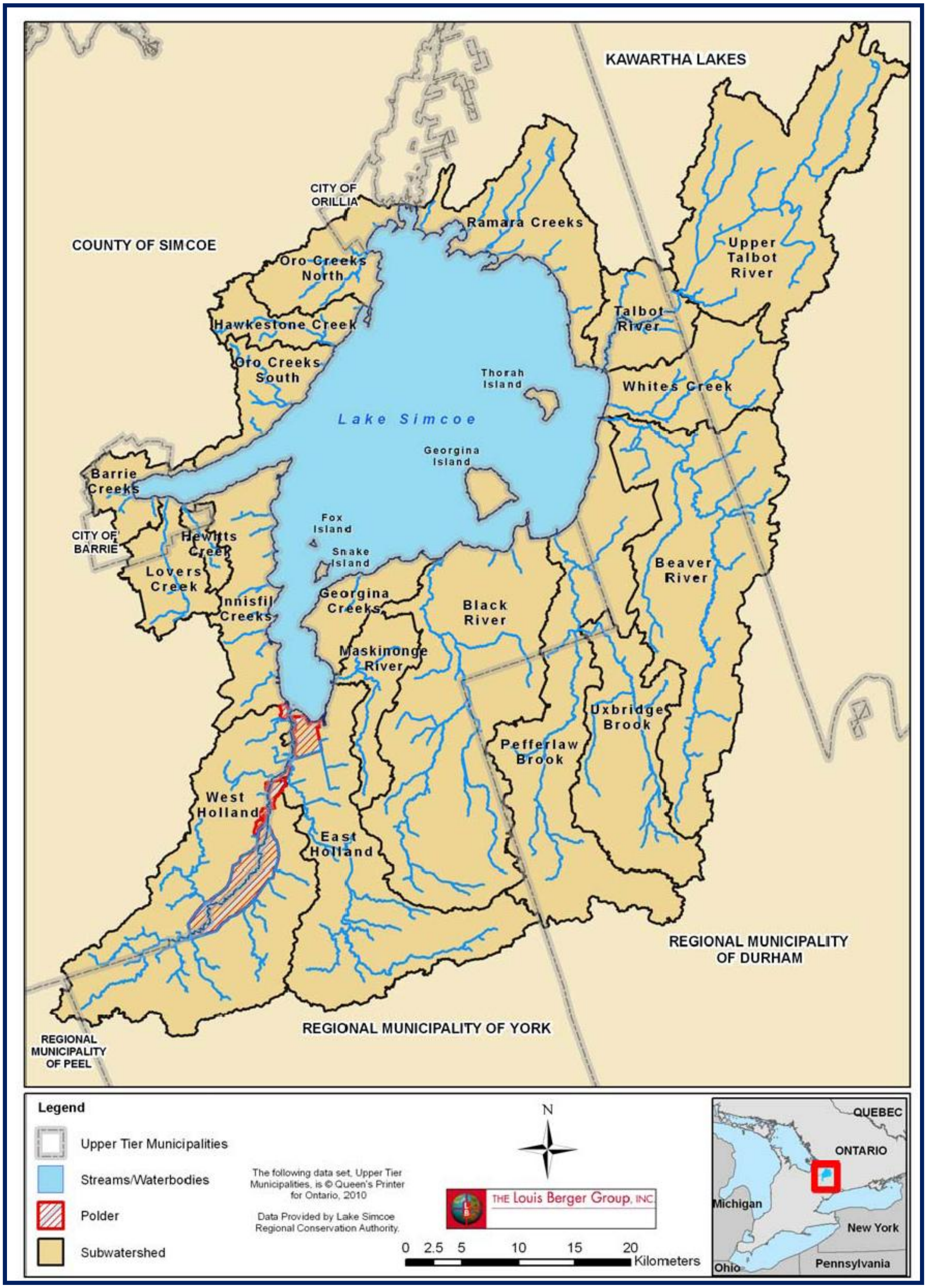


Table 1. Description of Berger (2010) Land Uses in the Lake Simcoe Watershed

Berger (2010) Land Use	Included LSRCA Land Use(s)	Land Use Description
Hay / Pasture	Non-intensive Agriculture	Hay and pasture fields, including the related agricultural buildings such as barns, silos and the farm residence. Fields are dominated with herbaceous vegetation and grasses with an understory of similar material in a state of decay. Weedy hay and/or pasture covers more than 50% of the area.
Crop Land	Intensive Agriculture	Cultivated row crops, including the related agricultural buildings (e.g., barns, silos and the farm residence), producing crops in varying degrees (e.g., corn and wheat) and includes specialty agriculture (i.e., orchards, market gardens, Christmas tree plantations and nurseries).
Sod Farm / Golf Course	Sod Farm	Sod farms.
	Golf Course	Golf courses, including lane ways, but not the isolated woodlots within, unless the area of the woodlots is < 0.5 ha.
Low Intensity Development	Estate Residential	A home including the manicured area around the home and driveway, within a natural heritage feature. The natural heritage feature is not included in the Estate Residential land use classification.
	Manicured Open Space	Cleared areas with a low density of trees, including lawns and landscaping. Land use is dominated by gardens, parkland and lawns, e.g., cemeteries, urban parks, ski hills and residential/industrial open space with a minimum size of 2 ha.
	Rail	Rail lines and the associated cleared adjacent areas.
	Rural Development	Properties not directly associated with an agricultural operation and that contain residential, commercial or other buildings, as well as a manicured open space, within a natural heritage or agricultural feature (e.g., estate residential or service station). On developed portions, these properties are under intensive use. Based on canopy cover, these areas will often appear as Cultural Savannah or Cultural Woodland in aerial photographs or satellite imagery. However, the presence of buildings and manicured lands identify the properties as Rural Development.
High Intensity Development[1] (Commercial /Industrial)	Commercial	Impervious properties that contain a building and an adjacent parking lot (e.g., shopping and strip malls, power centres, scrap yards). Excludes green land areas such as parks or river valleys.
	Industrial	Impervious properties that are not commercial and include industrial operations e.g., factories, manufacturing facilities, processing facilities, bulk fuel storage. Excludes green land areas such as parks or river valleys.
	Institutional	Schools, hospitals and other institutional structures. May include large storm water management ponds. Excludes green land areas such as parks or river valleys.
High Intensity Development[1] (Residential)	Urban	Urban related land uses including continuous ribbon development. Interpreted from aerial photographs or satellite imagery by many roof tops and/or groupings of 5 or more residential properties with a combined area of ≥ 2 ha. Residential properties include single and semi-detached dwellings, apartment buildings and associated out-buildings, driveways and parking lots. Excludes green land areas such as parks or river valleys.
Quarry	Active Aggregate	Areas that are currently being excavated or have recently been excavated. Identified by pits, extraction machinery, unvegetated landscape and/or piles of extracted materials. Active aggregate areas may contain open water.
	Inactive Aggregate	Former aggregate sites that have been recently revegetated; vegetation is established and growing. Depending on their characteristics, in aerial photographs or satellite imagery, these properties may appear to be comparable to an abandoned field or forming wetland.
Road	Road	Unpaved roads, including the shoulder. Does not include driveways.

Berger (2010) Land Use	Included Ecological Land Classifications (ELC(s))	Land Use Description
Transitional	Open Alvar	Cover varies from patchy shrub and tree cover to continuous meadow. Tree cover is ≤ 25%; shrub cover is ≤ 25%. Typically restricted to bare rock and patchy, shallow substrates.
	Cultural Meadow	Tree cover is ≤ 25% and shrub cover is ≤ 25%. The plant community is a result of, or maintained by, anthropogenic disturbances or culture.
	Cultural Thicket	Tree cover is ≤ 25% and shrub cover is > 25%. The plant community is a result of, or maintained by, anthropogenic disturbances or culture.
	Open Tallgrass Prairie	The ground layer of plants is dominated by prairie graminoids (grasses and grass-like plants, including sedges) such as Big and Little Bluestem, as well as Indian Grass. Tree cover is ≤ 25% and shrub cover is ≤ 25%. Soils are well drained with prolonged summer drought and frequent disturbance by fire.
Forest[2]	Cultural Plantation, Coniferous	Tree cover is > 60% of the area, with coniferous trees > 75% of the canopy area. The plant community is a result of, or maintained by, anthropogenic disturbances or culture.
	Cultural Woodland	Tree cover is between 35% and 60% of the area. There is often a large proportion of non-native plant species, and the plant community is a result of, or maintained by, anthropogenic disturbances or culture.
	Coniferous Forest	Tree cover is > 60% of the area, with coniferous trees > 75% of the canopy area.
	Cultural Plantation, Deciduous	Tree cover is greater than 60% of the area, with deciduous trees greater than 75% of the canopy area. The plant community is a result of, or maintained by, anthropogenic disturbances or culture.
	Deciduous Forest	Tree cover is > 60% of the area, with deciduous trees > 75% of the canopy area.
	Cultural Plantation	Tree cover > 60% of the area, with coniferous trees > 25% of the canopy area and deciduous trees > 25% of the canopy area. The plant community is a result of, or maintained by, anthropogenic disturbances or culture.
	Mixed Forest	Tree cover is > 60% of the area, with coniferous trees > 25% of the canopy area and deciduous trees > 25% of the canopy area.
Wetland[2]	Shrub Bog	Continuous *Sphagnum* spp. moss cover. Trees > 2 m tall cover ≤ 10% of the area and shrubs cover > 25% of the area. Land is rarely flooded but always saturated with water. Organic substrate > 40 cm deep consisting of *Sphagnum* peat.
	Treed Bog	Continuous *Sphagnum* spp. moss cover. Trees > 2 m tall cover 10% to 25% of the area. Land is rarely flooded but always saturated with water. Organic substrate > 40 cm deep consisting of *Sphagnum* peat.
	Open Fen	Sedges, grasses and low shrubs (< 2 m high) dominate; trees > 2 m high cover ≤ 10% of the area and shrubs cover ≤ 25% of the area. Land is rarely flooded but always saturated with water. Organic substrate > 40 cm deep consisting of moss or sedged peat.
	Shrub Fen	Sedges, grasses and low shrubs (< 2 m high) dominate; trees > 2 m high cover ≤ 10% of the area and shrubs cover > 25% of the area. Land is rarely flooded but always saturated with water. Organic substrate > 40 cm deep consisting of moss or sedged peat.
	Treed Fen	Sedges, grasses and low shrubs (< 2 m high) dominate; trees > 2 m high cover 10% to 25% of the area. Land is rarely flooded but always saturated with water with organic substrate and > 40 cm deep moss or sedged peat.

Berger (2010) Land Use	Included Ecological Land Classifications (ELC(s))	Land Use Description
	Meadow Marsh	Dominated by emergent hydrophytic aquatic plants (grow wholly or partially in water); tree and shrub cover ≤25%. Variable flooding regimes and water depth 2m.
	Shallow Marsh	Emergent hydrophytic aquatic plant cover ≥ 25%, tree and shrub cover ≤ 25% of the area. Water up to 2 m deep; standing or flowing water for much or all of the growing season.
Wetland[3]	Floating-Leaved Shallow Aquatic	Floating leaved aquatic vegetation covers > 25% of the area; no tree or shrub cover. Water up to 2 m deep; standing water is always present.
	Mixed Shallow Aquatic	A mixture of submerged and floating leaved aquatic vegetation covers > 25% of the area; no tree or shrub cover. Water up to 2 m deep; standing water is always present.
	Submerged Shallow Aquatic	Submerged aquatic vegetation covers > 25% of the area; no tree or shrub cover. Water up to 2 m deep; standing water is always present.
	Coniferous Swamp	Tree cover is > 25% of the area with trees > 5 m tall, and coniferous trees > 75% of the canopy area. Water depth is < 2 m with variable flooding regimes; standing water or spring (vernal) pooling covers > 20% of the ground.
	Deciduous Swamp	Tree cover is > 25% of the area with trees > 5 m tall, and deciduous trees > 75% of the canopy area. Water depth is < 2 m with variable flooding regimes; standing water or spring (vernal) pooling covers > 20% of the ground.
	Mixed Swamp	Tree cover is > 25% of the area with trees > 5 m tall; coniferous trees > 25% of the canopy area and deciduous trees > 25% of the canopy area. Water depth is < 2 m with variable flooding regimes; standing water or spring (vernal) pooling covers > 20% of the ground.
	Thicket Swamp	Tree or shrub cover > 25%, dominated by hydrophytic shrub and tree species (grow wholly or partially in water); tree cover ≤ 25%, hydrophytic shrub cover > 25%. Water depth is < 2 m with variable flooding regimes; standing water or spring (vernal) pooling covers > 20% of the ground.
Open Water[4]		Lakes, rivers and ponds including stormwater management ponds.

Notes: [1]High Intensity Development areas were further separated for the Tool into commercial/industrial and residential classes because the percentage of impervious area is typically much higher in commercial/industrial areas than in residential areas resulting in a greater amount of storm water runoff, [2]includes CANWET classes of Coniferous Woodland, Deciduous Woodland and Mixed Woodland, [3]includes CANWET classes of Emergent Wetland and Woody Wetland. [4]Not included in the Berger (2010) land classes but added for the purposes of the Tool recognizing that some development areas may have open water areas that should be included in calculations of phosphorus export.

3.2.1.1 Derivation of Export Coefficients

Export coefficients for all land classes were derived based on total phosphorus loading estimates reported by Berger (2010) for individual subwatersheds with the exception of High Intensity Development, which was derived from measured loads in MOE's Stormwater Management Monitoring and Performance Program (SWAMP, 2005; MOE, unpublished data) and Open Water which was derived from estimates of atmospheric loads to the surface of Lake Simcoe (Scott et al., 2006; LSRCA, 2009). The following describes the derivation and rationale for the selection of export coefficients from these sources for each land use in each subwatershed as provided in Table 1.

Berger (2010) provides total phosphorus loads (kg/yr) from the total areas devoted to specific lands uses in each of the 19 Lake Simcoe subwatersheds (Pefferlaw River and Uxbridge Brook subwatersheds were combined in the analysis as were the Talbot River and Upper Talbot River subwatersheds). Division of the total annual export (in kg) for each land use by the area (ha) devoted to that land use provides a standardized export coefficient in kg/ha/yr.

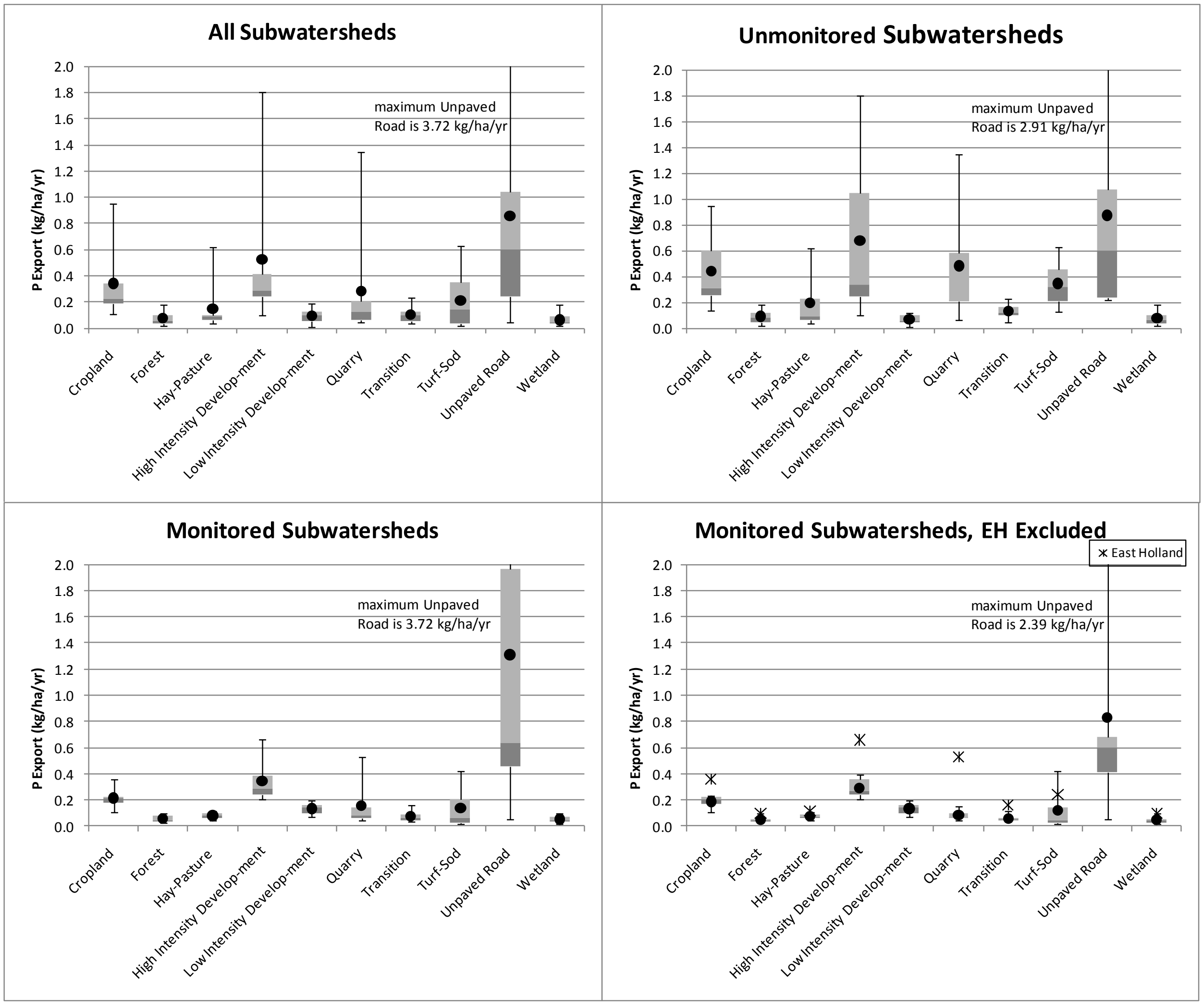
Phosphorus loads from groundwater, tile drainage and stream bank erosion were provided by Berger (2010) for the total subwatershed area only (and not for specific land uses) and so loads from these sources were allocated to the land use areas as follows:

1. **Groundwater** loads were added proportionally by area to all land use categories except High Intensity Development,
2. **Tile Drainage** loads were added to Cropland areas only, and
3. **Stream Bank Erosion** loads were added proportionally by area to Forest, Wetland and Transition areas

Groundwater loads were not allocated to High Intensity Development areas as these areas have a large amount of impermeable surfaces, thereby reducing groundwater infiltration and seepage. Tile drainage is used mostly for cropland agriculture. Stream Bank Erosion was only allocated to 'natural' land cover areas assuming that streams primarily occur in these land areas and are protected from development. Refined land use data would be required to determine the proportion of phosphorus loads from stream bank erosion in other land class areas (e.g., proportion of streams running through agricultural area or urban area). The resultant total phosphorus loads were used to calculate total phosphorus export (kg/ha/yr) for each land use in each subwatershed.

Considerable variance in phosphorus export coefficients derived from the Berger (2010) results occurred among subwatersheds, particularly among unmonitored subwatersheds (Table 2, Figure 3). Of the 19 subwatersheds, only 7 (with Pefferlaw River and Uxbridge Brooks subwatersheds combined) had measured data on flows and phosphorus loads for calibration of the CANWET model. Comparatively little variance occurred in export coefficients among these monitored subwatersheds, with the exception of higher export coefficients for most land classes in the East Holland River. Higher export coefficients in the East Holland River reflect the highly urbanized portions of that subwatershed as well as the amount of high intensity agriculture, which have both contributed to degraded water quality (LSRCA, 2010). The unmonitored subwatersheds were calibrated to estimated flows and total loads were estimated from the results of those monitored subwatersheds that were most similar in land cover (see Scott et al., 2006).

Figure 3. Boxplots showing variance in export coefficients derived from Berger (2010) for the Lake Simcoe Subwatersheds. Boxes represent 25th percentile, median and 75th percentile, whiskers are the minimum and maximum values, and the mean is denoted as the black dot.



Note: Excludes the export coefficient for Low Intensity Development (0.013 kg/ha/yr) for the East Holland River, which is suspected as being an error.

Some variation in phosphorus export between subwatersheds is expected for a given land cover type due to differences in environmental factors such as soil characteristics, physiography and runoff conditions. Principal Components Analysis (PCA, an analysis that displays patterns in multivariate data) was carried out to identify differences between subwatersheds based on the combination of key environmental factors affecting phosphorus export (see Appendix 4). Environmental factors included Soil K Factor (erosion coefficient), Slope Length, Base Runoff and Soil P (soil phosphorus concentration) as reported in Berger (2010) for each land use type in each subwatershed. Overall, results of the PCA did not reveal patterns in environmental characteristics that would explain the variance in export coefficients derived for the unmonitored subwatersheds (i.e., subwatersheds with similar environmental characteristics did not have

similar phosphorus export coefficients). By contrast, for the monitored subwatersheds, the East Holland River was characterized by higher Soil K Factor, Base Runoff and Soil P values in comparison to the other monitored subwatersheds, explaining the higher phosphorus export coefficients for this subwatershed.

Given the high variance in export coefficients for the unmonitored subwatersheds that cannot be explained by major environmental characteristics, phosphorus export coefficients for the Tool were derived for the monitored subwatersheds only and these were also applied to the unmonitored subwatersheds. For the monitored subwatersheds, export coefficients for all land use types were those developed from Berger (2010) results with the following exceptions:

- Low Intensity Residential Development for the East Holland River subwatershed – The calculated export for this land use (0.013 kg/ha/yr) was an order of magnitude lower than for other land cover classes in the subwatershed, including forest (Table 1). This suggests that the calculated value may underestimate the export from Low Intensity Residential Development in this subwatershed. The mean phosphorus export coefficient of 0.13 kg/ha/yr for the other monitored subwatersheds was therefore selected for Low Intensity Residential Development in the East Holland subwatershed.
- Unpaved Road - The export coefficients among monitored subwatersheds for Unpaved Road ranged from 0.049 to 3.72 kg/ha/yr. Given the large range in export values, the working group selected the mean export from the monitored subwatersheds (excluding the East Holland River) of 0.83 kg/ha/yr for Unpaved Road to be applied for all Lake Simcoe subwatersheds.
- Quarry for Whites Creek subwatershed – No quarries were reported in the Whites Creek subwatershed, therefore the mean export of the monitored subwatersheds (0.08 kg/ha/yr) was selected for this land cover class.

At the request of the MOE, phosphorus export coefficients of 1.32 kg/ha/yr were selected for high intensity urban residential areas and 1.82 kg/ha/yr for commercial/industrial high intensity development. These were developed from measured data from the 2006 SWAMP studies (MOE, unpublished data). These values are higher than those derived using the Berger (2010) modeled phosphorus loads for High Intensity Development, which ranged from 0.21 to 0.67 kg/ha/yr for the monitored subwatersheds (mean = 0.35 kg/ha/yr). These higher export coefficient values were selected because they were derived from measured data, have been used in several Lake Simcoe studies by MOE and LSRCA (Winter *et al.*, 2002, 2007; Scott et al., 2006; LSRCA, 2007, LSRCA and MOE, 2009) and are comparable to other published export coefficients for urban development. For example, Reckhow et al. (1980) reports urban export coefficients ranging from 0.19 to 6.23 kg/ha/yr (mean 1.91 kg/ha/yr, standard deviation 1.70 kg/ha/yr) and the US Environmental Protection Agency's (1983) nationwide urban runoff report distinguishes between residential and commercial land use with export coefficients of 1.3 kg/ha/yr and 3.4 kg/ha/yr, respectively. More details for this rationale are provided by the MOE and included in Appendix 8

In the PCA of the environmental factors that was described previously, the characteristics of the Georgina Creeks, Oro Creeks North and West Holland River subwatersheds (all unmonitored) were most similar to the East Holland River subwatershed with generally higher soil K factors, Soil P and base runoff that would be consistent with higher phosphorus export. The export coefficients for the East Holland River were therefore applied to these unmonitored subwatersheds.

The mean phosphorus export coefficients for all monitored subwatersheds (excluding the East Holland River) were applied to the remaining unmonitored subwatersheds (i.e., Hewitts Creek, Innisfill Creeks, Maskinonge River, Oro Creeks South, Ramara Creeks and Talbot/Upper Talbot River) as these were characterized by lower soil K factors, soil P and base runoff relative to the East Holland River.

A phosphorus export coefficient of 0.26 kg/ha/yr was selected for Open Water, which represents the atmospheric deposition of phosphorus in the Lake Simcoe watershed. This export coefficient was calculated from the mean measured atmospheric load of 19 tonnes/yr averaged over 5 years from 2002 to 2007 to the surface of Lake Simcoe (surface area = 722 km^2) (Scott et al., 2006; LSRCA, 2009). Note that phosphorus loads from atmospheric deposition to land are incorporated into the export coefficients for the various land cover classes. The atmospheric/open water coefficient should not be interpreted as loading from dust generated by land use activities such as agriculture or construction. It represents a regional atmospheric contribution. The means to estimate dust generation and loading are the subject of current research initiatives being undertaken by the MOE, the LSRCA and various research partners.

The final export coefficients for all subwatersheds are provided in Table 2. These are coded into the database tool to derive subwatershed-specific estimates of phosphorus export from specific land uses for the pre- and post-development (with no BMPs) calculations.

Table 2. Land-Use Specific Phosphorus Export Coefficients (kg/ha/yr) for Lake Simcoe Subwatersheds

Subwatershed	Phosphorus Export (kg/ha/yr)											
	Cropland	Hay-Pasture	Sod Farm/Golf Course	High Intensity Development		Low Intensity Development	Quarry	Unpaved Road	Forest	Transition	Wetland	Open Water
				Commercial /Industrial	Residential							
Monitored Subwatersheds												
Beaver River	0.22	0.04	0.01	1.82	1.32	0.19	0.06	0.83	0.02	0.04	0.02	0.26
Black River	0.23	0.08	0.02	1.82	1.32	0.17	0.15	0.83	0.05	0.06	0.04	0.26
East Holland River	0.36	0.12	0.24	1.82	1.32	0.13	0.08	0.83	0.10	0.16	0.10	0.26
Hawkestone Creek	0.19	0.10	0.06	1.82	1.32	0.09	0.10	0.83	0.03	0.04	0.03	0.26
Lovers Creek	0.16	0.07	0.17	1.82	1.32	0.07	0.06	0.83	0.06	0.06	0.05	0.26
Pefferlaw/Uxbridge Brook	0.11	0.06	0.02	1.82	1.32	0.13	0.04	0.83	0.03	0.04	0.04	0.26
Whites Creek	0.23	0.10	0.42	1.82	1.32	0.15	0.08	0.83	0.10	0.11	0.09	0.26
Unmonitored Subwatersheds												
Barrie Creeks	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
GeorginaCreeks	0.36	0.12	0.24	1.82	1.32	0.13	0.08	0.83	0.10	0.16	0.10	0.26
Hewitts Creek	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Innisfil Creeks	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Maskinonge River	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Oro Creeks North	0.36	0.12	0.24	1.82	1.32	0.13	0.08	0.83	0.10	0.16	0.10	0.26
Oro Creeks South	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Ramara Creeks	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
Talbot/Upper Talbot River	0.19	0.07	0.12	1.82	1.32	0.13	0.08	0.83	0.05	0.06	0.05	0.26
West Holland River	0.36	0.12	0.24	1.82	1.32	0.13	0.08	0.83	0.10	0.16	0.10	0.26

3.2.2 Methods - Calculating Pre-development Conditions

The pre-development or “existing conditions” phosphorus load is calculated through the following steps, by the user:

1. The user will rely on the information documented and detailed in the EIS for the development that will be used to support the planning application to the Municipality.
2. The user will choose the subwatershed or geographic area of the Lake Simcoe watershed in which the development is proposed from a drop down list provided by the database. If the development area spans two or more subwatersheds, the areas within each subwatershed should be modelled separately.
3. Specific land use classifications will be delineated and their boundaries overlain on an orthographic aerial photograph that shall be included in their submission.

   a. The user will select the Table 1 land uses that most closely match those delineated in their mapping and will document the rationale for the choice in a comment field for the database report. (e.g.,"ELC classifications a, b and c are present – these correspond to "forest"", or "actively tilled corn fields are classified as "cropland"").
   b. Land use classifications will be chosen by the user from a "drop down" list in the database, which will contain the land use classifications in Table 1.
   c. The user will provide areas (in ha) of each identified land use on the development site.
   d. The database will produce a table showing each land use, the area and export coefficient associated with each land use, the user comment or rationale for choice (as entered by the user in a text box) and the total area of the development.

4. The database links each land use classification to the respective phosphorus export coefficient for that land use for that subwatershed as shown in Table 2, calculates the total annual phosphorus load from each land use (as ha x kg/ha/yr) and sums the loads from each land use to produce the total annual pre-development load from the site.
5. The user may not adjust a particular export coefficient for site-specific characteristics in this version of the Tool, but user-defined export coefficients may be considered for future revisions of the Tool.
6. The database adds a final column of pre-development phosphorus loads for each land use to the table produced in Step 3d.

3.2.3 Methods - Calculating Post-Development Conditions

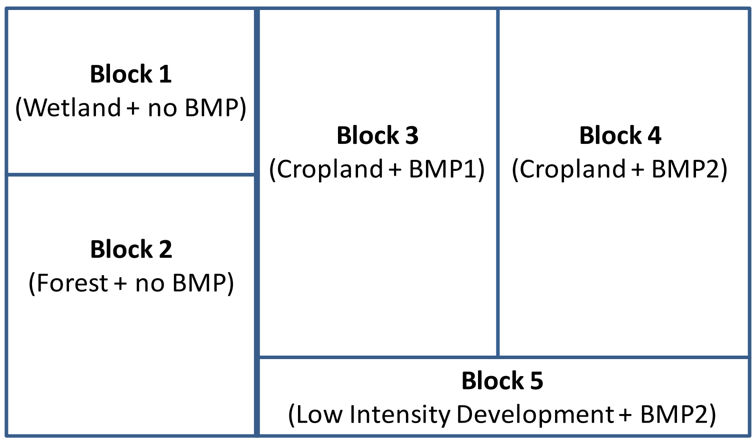
The post-development phosphorus load (without BMP implementation) will be calculated by the user, using the following steps:

1. The user will rely on the information on the proposed development that is documented and detailed in the planning application (EIS and SWM plans) to the Municipality.
2. The user will delineate the post-development land uses and overlay their boundaries on an orthographic aerial photograph that shall be included in their submission.
   a. Land uses will be defined using the same methods described for the pre-development conditions.
   b. The site will be divided into post-development blocks; each block with a unique combination of a land use and Best Management Practice or Treatment Train that will be applied to that land use in Module 3 (Figure 4).
   c. Land use for each block will be chosen by the user from a "drop down" list in the database, which contains the land use classifications in Table 1.
   d. The user will provide areas (in ha) of each post-development block.

e. The database will produce a table showing land uses, areas and export coefficients associated with each land use for each post-development block, and will display the total area of the post-development site.

f. The database will provide a check to make sure that the sum of post-development blocks is the same as the sum of the pre-development land use areas.

Figure 4. Schematic of post-development blocks that comprise a unique land use and BMP (or Treatment Train approach).



3. The database links each land use to the respective phosphorus export coefficient for that land use in that subwatershed (from Table 2), calculates the total annual phosphorus load from each block (as ha x kg/ha/yr) and sums the loads from each block to produce the total post-development load from the development site without BMPs.

4. The user may not adjust a particular export coefficient for site-specific characteristics in this version of the Tool, but user-defined export coefficients may be considered for future revisions of the Tool.

5. The database adds a final column of phosphorus loads (in kg/yr) for each post-development block to the table produced in Step 2e.

6. The database produces a summary showing:

   a. Pre-development phosphorus load (in kg/yr) for the entire development site,

   b. Post-development phosphorus load (in kg/yr) for each block and for the entire development site, and the

   c. Difference between pre- and post-development phosphorus loads (in kg/yr and as a %).

3.3 Module 3: Post-Development Load Reduction with BMPs

3.3.1 Approach

Phosphorus removal efficiencies for a variety of Best Management Practices (BMPs) were compiled from a literature review (Appendix 1). These were evaluated for their applicability to the Lake Simcoe watershed and a representative % removal efficiency for each applicable BMP was derived where possible, according to the methods outlined in the following sections. The user is not limited to using the BMPs and % removal efficiencies recommended in the Tool, although these do represent “pre-approved” BMPs and efficiencies that are acceptable to MOE. If custom BMPs or % removal efficiencies are used, supporting scientific rationale for their use must be provided in the Stormwater Management (SWM) plan for the development. This rationale will be reviewed as part of the approval process.

3.3.1.1 Selection of Appropriate BMP Phosphorus Removal Efficiencies

For any given stormwater management BMP there are a range of reported values that describe the phosphorus reduction that can be expected. This is also true for stormwater mitigation strategies relating to the construction phase of development projects (see Module 4). In both cases, there may be a wide range in reported percent reductions of phosphorus and these numbers may be highly qualified by various elements of BMP design or setting. For this reason, it is difficult to derive a single removal efficiency value for even narrow categories of BMPs and almost all stormwater practice documents that were reviewed reported a range of removal efficiency values for a given BMP category.

There are, however, reasonable decisions that can be made to derive appropriate and applicable single numbers that represent average expected phosphorus removal efficiency of various BMPs. This involves an examination of the regional variation that is inherent in the range of observed values together with any specific design aspects that may be contributing to the reported range. If, for example, the focus is confined to only those reported values that are regionally significant and the range in those values that apply to well designed or appropriately installed measures, then the result should be a narrower range in reported values.

Much of the confidence in selecting a phosphorus removal efficiency for any given stormwater management technique will result from the collection of a large number of regionally significant values that fall within a narrow range. In most cases, however, our review of available information showed that the availability of these types of data was the exception rather than the rule.

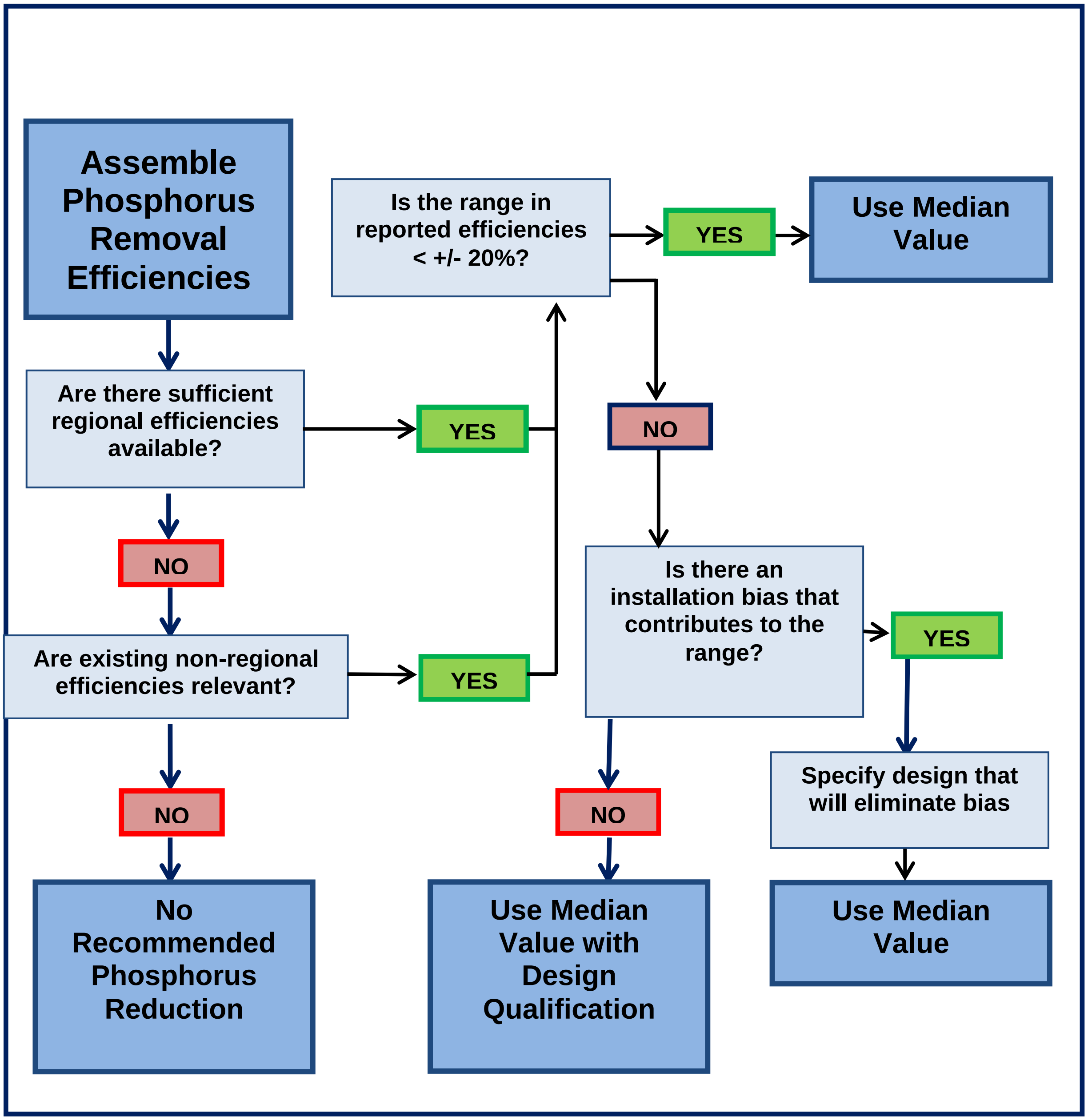
The decision tree shown in Figure 5 allows the consistent, objective selection of phosphorus removal efficiencies for individual stormwater or construction runoff management techniques by considering the range of reported efficiencies, the applicability of the reported efficiencies to the Lake Simcoe watershed and design characteristics that may influence the reported efficiencies.

In the example below, a phosphorus removal efficiency range of +/-20% (40% total) is used to describe an acceptable range in values (this corresponds generally to the median range of values observed for the techniques described in the documents that have been reviewed). The median of these values is chosen as a conservative estimate of phosphorus reduction. In the

most difficult cases where the ranges in reported values are >40%, the removal efficiency value may require a design qualification to be acceptable (see Figure 5).

The BMPs reviewed for the Tool (Table 3) are classes of BMPs and there may be unique features for any given BMP that make it more or less effective at phosphorus removal. Any BMP that is chosen should be assessed against the references given for the BMPs in Column 2 of Table 3 to determine whether or not the % phosphorus removal efficiency shown in Table 3 is applicable to the BMP of choice and for the specific characteristics of the development site. If not, the user should select the appropriate removal efficiency and provide details in support of that efficiency in the Stormwater Management (SWM) plan.

Figure 5. Decision tree for selecting appropriate phosphorus removal efficiencies for stormwater and construction BMPs.



3.3.1.2 Derivation of Single BMP Phosphorus Removal Efficiencies

Table 3 shows how the decision tree in Figure 5 is applied to the removal efficiencies that were assembled from the documents that were reviewed. The first step is to assess the efficiencies to identify those that are regionally significant. In this case, there is one BMP where the reported removal efficiencies are relevant to the Lake Simcoe watershed, namely perforated pipe infiltration/exfiltration system. The range of efficiencies for this BMP is less than 40% and so the median of the observed values is chosen as a single phosphorus removal efficiency for

that class of BMP. In two cases, (sorbtive media interceptors and soakways/infiltration trenches), although there are no Ontario phosphorus removal efficiencies reported in the review materials, the techniques are not limited by geography. The reported ranges in efficiency for these BMP classes are narrow so the median efficiency is chosen as a representative phosphorus removal efficiency. In all other cases, there are unacceptable regional differences and wide ranges in efficiencies that would not support the derivation of single representative phosphorus removal efficiencies. In the case of dry swales, the non-Ontario removal efficiencies may be usable, but the range of reported values is large such that it will be necessary to identify design criteria that will limit the range in efficiencies for this class of BMPs before a value can be chosen.

Table 3. Phosphorus Removal Efficiencies for Major Classes of BMPs Using the Decision Tree (Figure 5)

BMP Class	Reference IDs[1]	Reported Phosphorus Removal Efficiency (%)		Relevant to Ontario?	Range <40%?	Are Non-Ontario values acceptable?	Possible design criteria?	Median % Removal Efficiency
		Min	Max					
Post-development BMPs								
Bioretention Systems	8-10, 12,13, 34-38, 40	-1552	80	no	no	no	No	none
Constructed Wetlands	104, 106, 109	72	87	yes	yes			77
Dry Detention Ponds	104, 109	0	20	no	yes	yes		10
Dry Swales	24, 26-32	-216	94	no	no	no	possible	none
Enhanced Grass/Water Quality Swales	21, 104	34	55	no	yes	no	No	none
Flow Balancing Systems	106	77		no	?	yes	Min data	77
Green Roofs	2	-248		no	no	no	No	none
Hydrodynamic Devices	109	-8		no	?	yes		none
Perforated Pipe Infiltration/Exfiltration Systems	7, 4	81	93	yes	yes			87
Sand or Media Filters	104, 109	30	59	no	yes	yes		45
Soakaways - Infiltration Trenches	6, 104	50	70	no	yes	yes		60
Sorbtive Media Interceptors	111	78	80	no	yes	yes		79
Underground Storage	106	25		no	?	yes	Min data	25
Vegetated Filter Strips/Stream Buffers	6, 42, 104	60	70	no	yes	yes	Yes	65
Wet Detention Ponds	104-106, 109	42	85	yes	yes			63

Notes: [1]References associated with IDs are provided in Appendix 7.

The Table 3 values are recommended as general, representative phosphorus reduction efficiencies for major classes of BMPs and have sufficient documentation to demonstrate their effectiveness in Ontario's climate according to the decision rules provided above. ***They are only representative, however, under the assumption that they are built to design specification and maintained to design standards, to assure their effectiveness.***

Where the user wishes to use innovative BMPs, or if they can provide documented information or engineering design characteristics that alter the values provided in Table 3, then they would document their rationale according to the guidance provided (Sections 3.3.1.1 and 3.3.1.2) and demonstrate the effectiveness of the BMP in a manner acceptable to MOE in the SWM plan submitted for the development. Choosing to provide a different BMP or efficiency value may better reflect site-specific knowledge or emerging technologies but will result in a thorough review of the development application by the approving agency (ies), which may require more time to assess.

A treatment train approach, where more than one BMP is used in a series to treat stormwater runoff from the same land use area, can be used in the Tool. In a treatment train approach, the total phosphorus removal efficiency of the train is not necessarily the sum of the efficiencies for the individual BMPs in the train. This occurs because the efficiencies of several BMPs are influenced by phosphorus input concentrations. Treatment of runoff by one BMP may reduce the phosphorus concentration in the runoff to a level that reduces the effectiveness of the next BMP in the train. In addition, the Tool cannot anticipate or accommodate the many combinations of techniques that can make up a treatment train. The Tool, therefore, does not provide suggested phosphorus removal efficiencies for a treatment train. The user must provide the total phosphorus removal efficiency of the proposed treatment train and document the scientific rationale for that efficiency in the SWM plan for the development.

3.3.2 Methods - BMP Implementation

BMP selection and calculation of phosphorus load reductions for the post-development scenario will be completed by the user as follows:

1. The user will rely on the information documented and detailed in the SWM plan for the site that will be used to support the planning application to the Municipality.
2. The user will select the type of BMP (or a Treatment Train approach) that will be used to capture or treat runoff from each post-development block using the drop-down menu in the database. The user can select “Other” from the drop-down list if they plan to use an innovative BMP that is not coded in the database.
3. The user can choose to use the phosphorus removal efficiencies for the BMPs that are coded in the database, or can enter a custom efficiency. The User must enter a custom efficiency if a Treatment Train is selected.
4. If “Other” or “Treatment Train” are selected as a BMP, or if a custom efficiency is used for any BMP, the user will enter a brief rationale in the ‘rationale field’ that refers the reviewer to the SWM Plan for the full technical justification.
5. The database links each combination of post-development phosphorus load and chosen BMP for each block to the phosphorus removal efficiency of the chosen BMP to provide the load reduction that will be applied to runoff from that area.

6. The database calculates the total annual phosphorus load from each block (i.e., each land use/BMP combination) with BMP implementation and sums the loads to produce the total post-development load with BMPs for the site.
7. The database produces a summary showing:
    a. Pre-development phosphorus load (in kg/yr) for the entire site,
    b. Post-development phosphorus load (in kg/yr) for the entire site, with and without BMPs, and
    c. Change in phosphorus load from pre-development conditions, with and without implementation of BMPs (in kg/yr and as a %).

3.4 Module 4: Construction Phase Phosphorus Loads

3.4.1 Approach

Quantification of phosphorus loads during construction is challenging given the variance in timing of construction processes, storm timing and frequency and site characteristics. In addition, phosphorus concentration in soil will vary across a site, and with depth. The Tool is therefore based on estimating soil loss during construction, and the effectiveness of various BMPs in preventing soil loss. A BMP that reduces soil loss from construction activity by 65% is assumed to reduce phosphorus loss by 65%, regardless of the actual concentration of phosphorus in the soil.

The approach used in this guidance is based on the Universal Soil Loss Equation (USLE) as described by Stone and Hilborn (2000). Users of the Guidance are required to divide potential development sites into blocks of continuous slope and relatively uniform soil characteristics and provide information needed to populate the USLE. From this it is possible to approximate soil loss during the construction phase. The construction phase assessment does not include losses of soil-bound phosphorus to the atmosphere by wind erosion, as the science is not well-enough advanced to guide estimates from this pathway. The Tool addresses losses through surface runoff only.

TRCA (2006) and MOE (2003, 2006) have developed Erosion and Sediment Control Guidelines for Urban Construction which are excellent resources for designing site controls to reduce sediment and nutrient loss during construction, but which provide no indication of the potential soil loss either with or without controls in place. Where available, the effectiveness of erosion and sediment control BMPs that apply during the construction phase to minimize soil, and hence phosphorus, runoff have been documented in this Guidance. These reductions are included as part of the calculation approach used in the database tool provided.

Using the USLE and documented construction phase BMPs, a reasonable estimate of construction phase sediment loading is produced.

3.4.2 Calculating Construction Phase Loading

The quantification of expected soil loss from a construction site is an uncertain process, even under the most well-defined conditions. Determining expected loss reductions from the use of various on-site BMPs adds to the uncertainty. Even with inherent uncertainty, however, this Guidance proceeds from the principle that the process of quantifying soil and nutrient losses as part of the planning and approval process will have a beneficial impact on water quality regardless of whether the estimated loads are actually realized, as long as the appropriate BMPs are selected and properly implemented in a manner that minimizes soil losses from the site. The process of estimating construction phase loadings and the means to minimize them is one of awareness that can be translated into the site development process.

This Guidance provides a means for users to estimate sediment and particulate phosphorus loading from the construction phase using the Universal Soil Loss Equation as described in Stone and Hilborn (2000) where average annual estimated soil loss (S_L) in kg/year from the construction site is calculated as:

$$S_L = \sum 2241.7 \times R \times K \times LS \times C \times P \times A_i$$

Where:

2241.7 is a unit conversion from tons / acre to kilograms per hectare;

R is the rainfall and runoff factor by geographic location with a value of 90 for the Lake Simcoe basin;

K is the soil erodibility factor based on soil textural class and organic matter content of exposed soil according Table 4;

LS is the slope length gradient factor which can be calculated as:

$$LS = [0.65 + 0.0456\ (\%\ slope)] + 0.006541\ (\%\ slope)^2 \times (\text{slope length in meters} / \text{constant})^{NN}$$

Where:

The user would provide values for % slope and slope length.

Constant = 22.1, and

NN is determined according to slope via Table 5.

C is the C factor. The C factor in agricultural applications of the USLE is the product of a crop type factor and a tillage method factor which produces an estimate of the portion of the year during which there is exposed soil that is unprotected by vegetative cover. For a construction site application this could be calculated using input from the user as:

C = (months during construction phase that soil is exposed/12) / (duration of construction in months/12)

Table 4. K Factor Data (Organic Matter Content)

Textural Class	Average	Less than 2 %	More than 2 %
Clay	0.22	0.24	0.21
Clay Loam	0.30	0.33	0.28
Coarse Sandy Loam	0.07	--	0.07
Fine Sand	0.08	0.09	0.06
Fine Sandy Loam	0.18	0.22	0.17
Heavy Clay	0.17	0.19	0.15
Loam	0.30	0.34	0.26
Loamy Fine Sand	0.11	0.15	0.09
Loamy Sand	0.04	0.05	0.04
Loamy Very Fine Sand	0.39	0.44	0.25
Sand	0.02	0.03	0.01
Sandy Clay Loam	0.20	-	0.20
Sandy Loam	0.13	0.14	0.12
Silt Loam	0.38	0.41	0.37
Silty Clay	0.26	0.27	0.26
Silty Clay Loam	0.32	0.35	0.30
Very Fine Sand	0.43	0.46	0.37
Very Fine Sandy Loam	0.35	0.41	0.33

Table 5. NN Values

S	< 1	1 ≤ Slope < 3	3 ≤ Slope < 5	≥ 5
NN	0.2	0.3	0.4	0.5

P is the support practice factor and represents BMP practices that contribute to reducing soil erosion on the slope (“source reduction”) and practices that capture sediment at the bottom of the slope (“capture reduction”).

$$P = \{(1- BMP_{prev}) * a_1 + (1 - a_1)\} * \{(1 - BMP_{cap}) * a_2 + (1 – a_2)\}$$

Where:

BMP_{prev} is the efficiency of the erosion prevention BMP applied on the slope (i.e., source reduction)
a_1 is the portion of the slope the erosion prevention BMP is applied to
BMP_{cap} is the efficiency of the down gradient sediment capture BMP
a_2 is the portion of the slope runoff intercepted by the sediment capture BMP (i.e., capture reduction)

A_i is the area of slope i. Soil loss for the site is the sum of soil loss from each slope that comprises the site.

The phosphorus load (P_L) from the construction site area is the product of the soil loss (S_L), the subwatershed soil phosphorus concentration ($Soil_P$) and the duration of construction phase in years (D_{yrs}):

$$P_L = S_L * Soil_P * D_{yrs}$$

Soil phosphorus concentration was originally intended to be a subwatershed value derived from the CANWET model. However, due to the variability between subwatersheds it was decided that a single soil phosphorus value of 0.0004 kg-TP/kg soil would be provided for all subwatersheds. This value was derived from the mean of subwatershed aggregate values used in Berger (2010). The CANWET model applies an empirical enrichment factor to the initial estimate of soil phosphorus to account for the greater phosphorus adsorption surface of smaller particles that make up a greater portion of eroded material.

A summary of user supplied data requirements is presented in Table 6. This information is used as input to the included database tool to calculate an estimated base phosphorus loading from the construction phase.

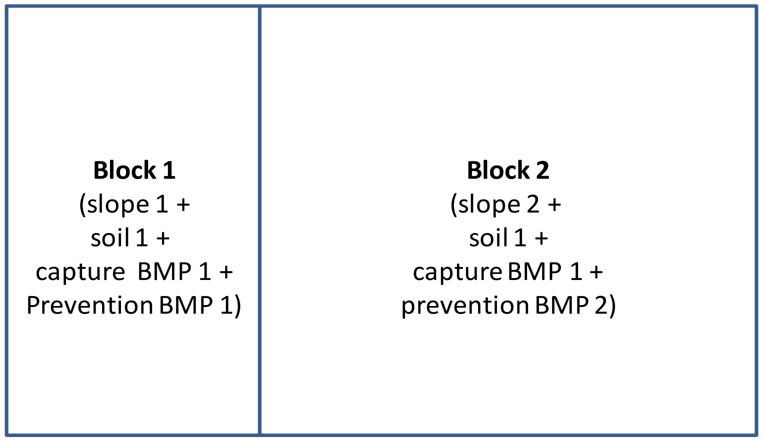
Table 6. Input Requirements for Calculating Construction Phase Soil Loss

Key Factors (to be input by guidance users for each continuous sloping portion of the construction site)
Area of slope being considered
Predominant soil texture class and organic matter content
Surface Slope Gradient (%)
Length of Slope
Aggregate efficiency of BMP(s) to be used on this sloped portion of the site
Duration of exposed soil on site
Duration of construction phase

In order for this approach to produce a defensible estimate of sediment and phosphorus loading from a construction site, the site must be divided into a series of sub-areas, or ‘blocks’, each with relatively uniform slope and soil characteristics to which a specific set of BMPs will be applied (Figure 6). The soil loss equation is applied to each block and the estimated site load is the summation of loads from each sub-area. Calculated loading from each block needs to consider the amount of time during the construction process that each area is undisturbed, exposed, stabilized and with or without sediment controls to capture runoff.

If a construction phasing approach is to be used for construction, the undisturbed portions of the site are assumed to contribute their pre-development loading rates of sediment and phosphorus until clearing and grading takes place after which the USLE estimate is applicable for the period of time until the ground reaches its post-development state.

Figure 6. Schematic of construction phase blocks that comprise relatively uniform slope and soil characteristics and a unique capture BMP and prevention BMP combination.



3.4.3 Construction Phase BMPs

In all cases there is a requirement that BMPs are maintained throughout the duration of the construction phase in order that they continually operate at their design efficiency. The literature reports a wide range of soil loss from uncontrolled construction sites. For example between 5 and 50 tonnes per hectare per year of sediment is reported by Dreher and Mertz-Erwin (1991). Properly installed and maintained controls and BMPs can significantly reduce losses of soil and phosphorus and these construction phase BMPs can be divided into general categories:

- Detention / retention systems – detain stormwater in some form of storage. This practice can produce a number of benefits including reduced flow velocity and hence reduced sheer stress on soil particles, reduced peak flows and increased sedimentation.
- Flow control structures – divert flow from off-site, less disturbed or stabilized areas and route it around areas with exposed soils thus preventing erosion in vulnerable areas. Structures may also be used to reduce sheer stress from runoff by reducing flow velocity through provision of storage.
- Construction practices – include strategic sequencing and phasing of site activities, strategic grading and minimizing soil loss from vehicle traffic leaving site.
- Filtration systems – include various methods of physical filtration of sediment from stormwater prior to release.
- Infiltration systems – capture and infiltrate stormwater.
- Soil erosion prevention – includes use of vegetative covers, mulches and fibre blankets to protect exposed soils from the erosive forces of incident rainfall and overland flow.

Schueler and Holland (2000, article 52) provide ten (10) key elements that are needed for an effective erosion and sediment control plan for construction sites. These are summarized below.

Minimize unnecessary clearing and grading

Clearing and grading must be carried out within a stream protection and sediment control strategy. These activities should be greatly restricted in sensitive areas including stream buffers, forest and wetland conservation areas, springs, seeps and infiltration areas, steep slopes, highly erodible soils and other environmentally sensitive features. These should be identified in both the site EIS and the SWM plan.

Only areas that need to be cleared and graded as part of the development foot print or in order to access the site should be disturbed. Features to be preserved need to be clearly marked on site plans and in the field. Contractors need to be made aware of and have a clear understanding of how the sediment control strategy and minimization of clearing is to take place.

Minimizing site disturbance is a critical factor in reducing the cost of other sediment and erosion control measures on a construction site.

Protect water courses and stabilize stream banks

Streams and watercourses are sensitive to construction activities. Where these features exist on a construction site, no clearing should be permitted within a prescribed setback in order to provide an adequate buffer. These should be identified in both the site EIS and the SWM plan.
Additional protection should be installed along the perimeter of the watercourse buffer in the form of a silt fence, swale or other form of filtration to intercept stormwater runoff carrying sediment from upland portion of the site to a watercourse.

Existing and future drainage ways traversing a construction site are a major conveyance of sediment from the site to watercourses as well as also being very prone to erosion from stormwater runoff. Ideally, drainage ways should be protected as a grass-lined channel or through the use of sod, erosion control blankets or jute netting. Check dams may be appropriate to slow stormwater passing through drainage ways and provide an opportunity for suspended sediment to settle. Check dams can also provide some storage to reduce peak flows that can impact receiving watercourses.

Use construction phasing to limit soil exposure

Large scale clearing and grading is a typical current practice for development sites, but such practices should be avoided because they produce the greatest loss by maximizing the duration that soils are exposed and the area of exposure. Construction phasing is an alternate approach whereby the site is divided into smaller sub-areas where clearing and grading take place only immediately before construction on a portion of the site. All other sub-areas of the site are either undisturbed or stabilized within 30 days of grading. This means that site grading cannot take place all in one step as is the current typical practice. Typical sediment load reductions compared with conventional non-phased approaches are estimated at around 40% for a subdivision development (Schueler and Holland (2000, article 54). Combining this reduced sediment loss with other practices that capture already suspended sediments can lead to a much reduced loss rate from a well managed site. Prevention of erosion is especially important on sites with fine soil particle sizes that can be very challenging to remove once they are suspended (Brown and Caraco, 1996)

The size of the project and the economics of grading in multiple phases are certain to be a consideration in the use of a phased approach. Schueler and Holland (2000 article 54) suggests a minimum 10 ha threshold. Because grading is an expensive process and involves the mobilization of large equipment it may be cost prohibitive to grade one phase, remove or idle equipment and then return it for grading a subsequent phase some time later.

If a phased approach is to be used, planning for it must begin in the early stages of the project as there is an added level of complexity inherent to the approach that will require additional coordination. The planning should set out “triggers” for initiating a subsequent phase and also for stabilization of the current phase. The sequence of construction for each phase and also for the overall project needs to be determined from the beginning.

Cut and fill must be balanced within each phase without dependence on undisturbed areas for storage of material or provision of additional material for the current phase. Therefore the existing and planned topography must be considered when delineating each phase of construction to ensure that a balance can be met.

Stormwater management, roads and other infrastructure need to be considered in each phase. Where stormwater management facilities are to exist within the final site plan, the phase(s) that contain these facilities should be initiated earlier in order that they can provide stormwater treatment for the disturbed site in advance of completion. Temporary facilities may need to be used to protect already completed phases or adjacent properties and watercourses that will receive runoff from the construction site.

Phasing planning also needs to consider the impact of on-going construction on completed phases both from disturbance from construction activities and traffic. This may involve the use of alternate access roads for each phase.

For each phase, erosion and sediment control practices need to be planned and installed prior to disturbance. Planning needs to define when and where stabilization techniques are to be used following grading. Maintenance and inspection schedules for sediment control elements must be specified and followed.

Although a phased approach will likely incur an added cost to the developer, this should be considered along with the reduction in cost of treating larger amounts of sediment laden stormwater through various capture techniques that require space, construction time, materials and subsequent maintenance.

Immediately stabilize exposed soils

The objective on every construction site should be to establish grass or mulch cover within two weeks after soils are exposed. Therefore fibre mulch is needed to stabilize soils during months when grass germination is slow or not possible. Compilation of data from four (4) studies of 17 erosion prevention techniques involving various types of ground cover including mulches, straw, compost, fibre and synthetic blankets suggests that establishing a soil cover immediately after soil exposure can reduce soil and/or TSS loss by 29% to 99% with an approximate median value of 90%. Slopes in these studies ranged from 9% to 34% with various soil textures and storm events (Schueler and Holland, 2000, article 55).

Lee and Skogergboe (1985) found a 99% reduction in suspended solids load after seeding exposed soil to increase biomass from zero to 2,762 kg/ha.

An effective erosion and sediment reduction plan for the site will need to consider contingency strategy for stabilizing soils when project schedules shift and climate conditions impact the establishment of vegetative cover.

Protect steep slopes and cuts

Steep slopes are the most highly erodible surface on a construction site. Land clearing, vegetation stripping, grading, cut-and-fill and other practices that disturb soil on a slope should not be conducted.

If soil disturbance on a slope cannot be avoided, upland flow should be prevented from flowing down over a slope. Severe gullies can form quickly from overland flow on a disturbed slope. Gully erosion results in large amounts of soil loss from a slope and can cause a slope to fail.

Upland flow should be diverted around the slope by installing an earthen berm, ditch or perforated drain along the top of the slope. Runoff will discharge from the end of the diversion and the designer should ensure a stabilized outlet with capacity for a 10 year storm event, and stabilized diversion channels.

A silt fence anchored securely into the ground at the top of the slope may be used in conjunction with a permanent diversion feature to capture sediment on slopes less than 15 m long. A silt fence is not effective at diverting overland flow as it is permeable. If mid- or base-of-slope sediment capture is required, and silt fence is installed to capture sediment, the silt fence must be installed to adequately handle high water velocities and sediment movement down the slope, otherwise water and sediment will overload or knock the silt fence down. If a traditional silt fence is not adequate for mid- or base-of-slope application, a scoop trap or super silt fence may be a suitable alternative. Schueler and Holland (2000, article 56) describes these structures.

Temporary seeding, mulch or other surface treatments may not be effective in preventing erosion on steep slopes. Additional stabilization measures such as erosion control blankets, geogrids/geotextiles and mulch binders are often required on steep slopes. In winter, steep slopes may be protected by a plastic sheet cover (like covering a soil stockpile). All stabilization measures must be appropriately tied-in to the ground at the top of the slope to prevent overland flow from flowing beneath them. Stabilization methods are not designed to prevent slope failure, only reduce erosion.

Install perimeter controls to filter sediments

Perimeter controls are installed at the edge of a construction site to retain or filter runoff before it leaves the site. Silt fences and earthen berms are two of the most common perimeter controls.

Silt fences are moderately effective in filtering sediment when installed, located and maintained properly, with reported sediment removal efficiencies ranging between 36% and 86% with a median of 70% reported in four (4) studies summarized in Schueler and Holland (2000, article

56). However, silt fences are commonly improperly installed and maintained, significantly reducing this efficiency.

Some basic guidance for proper installation of silt fencing includes:

Silt fencing must be aligned parallel with slope contours down gradient of the exposed area. Positioning should reflect the need for erosion and sediment control above property boundaries, but should consider construction traffic. The edges of the silt fence need to curve uphill to prevent flow from bypassing it. The length of the contributing slope should be no more than 30 m. Fabric must be deeply entrenched to prevent undercutting. Spacing between posts should be less than 2.5 m and portions of the fence receiving concentrated flow need to be reinforced.

If runoff does not infiltrate the ground faster than it accumulates behind berms or silt fences, it will flow to other areas of the construction site or will run off of the site. Runoff will discharge from the ends of berms and the designer should ensure a stabilized outlet with capacity for a 10 year storm event, stabilized diversion channels and berms (i.e., appropriate surface cover). There are typically fewer maintenance problems with earthen berms than silt fences, provided berms are designed to suit the site's conditions and climate. For small sites, a compacted 0.66 m high berm made of compacted soil and covered with an appropriate surface treatment is usually sufficient.

Straw bales should not be used as perimeter berms as they typically do not retain sediment well, can add to dissolved phosphorus loads in runoff and are commonly improperly installed and maintained.

Gravel or clear stone can be installed in conjunction with silt fences or earthen berms as a filtering outlet on small sites, provided that sediment will not flow through or plug the filter during construction or between maintenance cycles.

Even when erosion and sediment control BMPs are properly installed and maintained, construction sites will still discharge high concentrations of sediments during large storm events. Therefore, erosion and sediment control BMPs should include a trap or basin to settle sediments in runoff, before runoff leaves the site. For most soils, settling devices must operate at 95 – 99% efficiency to produce a non-turbid discharge. However, traditional settling basins have been shown to have variable efficiency because of the distribution of sediment grain size. Finer sediments take more time to settle out and can comprise the larger portion of the sediment load. The traditionally simple designs of settling basins may not be adequate to capture these fine materials.

To improve sediment settling efficiency, settling basins should include features to increase water retention time or decrease water energy/flow to promote more efficient sediment settling. These features could include: greater storage volume, internal geometry which reduces water flow rates, gentle side slopes, multiple cells, perforated riser pipes, and the use of baffles, skimmers and other outlet devices to reduce sediment discharge.

A detailed inspection and cleanout/maintenance plan should also be implemented with the use of settling basins/devices to increase efficiencies.

Use contractors trained in the use of sediment control techniques

The most important aspect of erosion and sediment control is having contractors on the construction site that are experienced in the installation and maintenance of erosion and sediment control BMPs that are appropriate to the site's conditions. This includes contractors who conduct earth works with minimal footprints and structure work to reduce erosion prone surfaces.

Erosion and sediment control courses are available from construction organizations and through some municipalities and conservation authorities (e.g., Toronto Regional Conservation Authority). Contractors with training from these courses may provide better erosion and sediment control services than those without. Hiring an environmental consultant or engineer with professional erosion and sediment control design is also advisable, especially on large or complex sites.

Adjust planning on-site to ensure appropriateness

Erosion and sediment control plans and best management practices are usually designed at the desk top. Site conditions may not be the same as those on site plans, and site conditions may change unexpectedly during construction. Therefore, erosion and sediment control plans and BMPs should be monitored and revised as necessary, to capture sediment before it migrates off of the construction site.

If sediment migrates off of the site, especially if the sediment contains contaminants, third party properties or the environment may be damaged, fines may be laid and the property owner may be mandated by the MOE or local conservation authority/municipality to remediate the impacts. Therefore, it is crucial to capture sediment before it leaves a site. If planned erosion and sediment control BMPs are not effectively capturing sediment, or it appears that the BMPs may fail, the erosion and sediment control plans should be amended.

Re-assess effectiveness of sediment management following large storms

Following the first storm on a site, the effectiveness of the erosion and sediment control BMPs should be assessed. This "first event" assessment will indicate if erosion and sediment control BMPs are appropriate or need to be amended, or if additional BMPs are required.

Include maintenance planning and implementation for sediment control practices

Sediment control features capture sediment and they become ineffective if accumulated sediment fills their basins or pore spaces. Therefore, maintenance (e.g., sediment removal) of sediment control features is required. The maintenance interval should be determined based on the type of erosion control feature installed, and intensity of erosion on the site (e.g., silt fences may need more frequent maintenance than large settling ponds).

Additionally, if construction activities continue longer than expected or unexpected site conditions arise (e.g., larger exposed areas or more precipitation than anticipated), maintenance may be required on 'one time' installation features that wouldn't normally require maintenance.

For the purpose of simplicity this Guidance will assume that soil and nutrient loss rates are uniform throughout the year and that the efficiency of BMPs also remains unchanged. These factors can be revised as information becomes available in the future.

3.4.4 Effectiveness of Construction Phase BMPs

The Database Tool uses a 2-tier reduction approach to calculating sediment reduction from construction phase BMPs. The first BMP reduction is applied to the base load as determined from the USLE equation that assumes no protection. This "source reduction" is applied to account for load reductions resulting from erosion prevention measures. These measures, and associated reductions and rationale are:

- Vegetative cover – 99% reduction after construction site areas are returned to vegetative cover (grass or open field vegetation) during the construction phase
- Mulch, fibre or geotextile blankets and mats – 90% reduction for a) areas where mulch coverage is maintained, mulch is applied thickly enough to prevent erosion from runoff and a second tier BMP is installed at the point of runoff, or b) areas that are completely covered with a fibre or geotextile blanket that is secured and maintained to prevent erosion from runoff and a second tier BMP is installed at the point of runoff.
- Check dams – Check dams do retain coarse particulate matter and associated phosphorus but the efficiency of these devices is not yet well enough known to provide an associated reduction.

The second tier BMP reduction is applied to the resulting load at the bottom of the slope or prior to the load leaving the site. This "capture reduction" is applied to account for load reductions resulting from sediment capture measures. These measures include practices such as:

- Dry Detention Ponds – 10% reduction as described in Section 3.3, Table 3
- Wet Detention Ponds - 63% reduction as described in Section 3.3, Table 3
- Vegetated Filter Strips/Stream Buffers – 65% reduction as described in Section 3.3, Table 3
- Silt fences – 70% reduction for areas where silt fences are properly installed, maintained and inspected to effectively to capture sediment.
- Sand or media filters (filter tubes and bags) - 45% reduction as described in Section 3.3, Table 3
- Soakaways - Infiltration Trenches – 60% reduction as described in Section 3.3, Table 3
- Anionic Polymer Runoff Treatment – 91% reduction for treatment of runoff from an area where TSS concentration in the runoff ranges from 171 to 706 mg/L.

The combined reduction in sediment load is represented as the "P" factor in the soil loss equation (Section 3.4.2) for each slope unit assessed. We assume that the same efficiency of these BMPs is applicable to runoff that has already been subject to Tier 1 BMPs, however, the effectiveness of the Tier 2 BMPs is likely reduced since larger particle sizes are already retained by Tier 1 BMPs leaving the more difficult to retain finer particles.

Additional techniques and details for construction phase reduction of sediment loss are presented in Appendix 2.

3.5 Analysis to Estimate Changes in Phosphorus Load

The intent of Policy 4.8e is to minimize phosphorus loadings to the lake from development and the test of meeting that intent has been interpreted as:

Post-Development Load < or = Pre-Development Load.

The MOE recommends that municipalities require that phosphorus loading from the construction phase be minimized in support of other related designated policies in the LSPP (i.e., Policy 4.20 and 'have regard' fro Policy 4.21), with the objective that:

Post-Development Load + Construction Load < or = Pre-Development Load.

In consideration of the above, the MOE recommends that municipalities approve development as site specific appropriate if:

a) Post-development load < or = pre-development load, and

b) (Post-development + amortized construction phase) load < or = pre-development loading,

OR

If (Post-development + amortized construction phase) load > pre-development loading,

THAT

All reasonable and feasible construction phase BMPs have been identified for implementation, documented and accounted for in the application.

In consideration of the above, the database tool calculates resulting loads from each of the four modules and determines the net impact in terms of the phosphorus budget associated with the proposed development site. The analysis needs to distinguish permanent changes in phosphorus load resulting from changes in land use (i.e., pre- vs. Post-development) from temporary loadings during each year of construction. The Database Tool calculates loadings on an annual time step for pre-, post and as a total load for the entire duration of the construction phase.

The impact of the construction phase load to the lake from any one year will be fully assimilated within eight years, as the average residence time of water in Lake Simcoe is 7.5 years (Scott et al., 2004). The annual contribution from the construction phase load is therefore calculated by dividing the total construction phase load by 8 (to "amortize" the loading from construction over the residence time of water in Lake Simcoe) and adding the result to the post-development condition. If the resulting load exceeds the pre-development load, the applicant would determine additional construction phase BMPs that will reduce the load to below pre-development levels or, alternatively, shorten the construction phase to meet the requirement that all reasonable and feasible construction phase BMPs have been considered for the development. This approach is illustrated for four hypothetical scenarios in Table 7.

Table 7. Sample Analysis to Achieve Reductions in Phosphorus Load. All figures are in kg/yr.

Pre Development Load		**600**
Post Development Load		480
Construction Phase Annual Load		120
Scenario 1 Two Year Build Out		
Construction Phase - 2 Year Total Load	240	
Construction Phase - Amortized annual load over 8 years		30
Post Development Load		480
Total Load : Post Development + Construction		**510**
Conclusion : Net Reduction in Load		
Scenario 2 Twelve Year Build Out		
Construction Phase - 12 Year Total Load	1440	
Construction Phase - Amortized annual load over 8 years		180
Post Development Load		480
Total Load : Post Development + Construction		**660**
Conclusion : No Net Reduction in Load		
Scenario 3 Reduce Build Out Time to Six Years		
Construction Phase - 6 Year Total Load	720	
Construction Phase - Amortized annual load over 8 years		90
Post Development Load		480
Total Load : Post Development + Construction		**570**
Conclusion : Net Reduction in Load		
Scenario 4 Twelve Year Build Out + Improve BMPs by 50%		
Construction Phase - 12 Year Total Load	720	
Construction Phase - Amortized annual load over 8 years		90
Post Development Load		480
Total Load : Post Development + Construction		**570**
Conclusion : Net Reduction in Load		

The final component of phosphorus management is verification that the development and its construction are carried out to achieve the development plan and BMPs that informed the phosphorus budget development. The Tool is developed with the purpose of demonstrating, through scientifically valid methods, the conditions under which "no net phosphorus load" can be achieved and verified at the planning stages of development. The need for verification that the development was implemented as proposed needs to be considered, but is beyond the scope of this document and must be addressed as part of the planning approval and implementation process.

4. Future Directions

The methodology for calculating a site level phosphorus budget presented in this Guidance needs to be considered a “living document” that is updated over time as new information and technology become available, or as the LSPP Phosphorus Reduction Strategy or other policies change. The following should be considered as part of the future direction of the evolving Guidance:

- Pphosphorus export coefficient values should be updated in response to new monitoring or modelling initiatives at the subwatershed, catchment, and potentially site level of resolution.

- The methodology provided in this Guidance uses the standard Universal Soil Loss Equation (USLE) as described by Stone and Hilborn (2000) rather than the more recent RUSLE2 which is more complex and involves the use of a more definitive database of parameter values. Future reviews might consider whether the RUSLE2 approach would produce a more reliable result and if data is available to support its use.

- This Guidance and the associated Database Tool could be made a web-based utility in the future in order to allow for easier updating of tables and parameters used in the calculations. We note, however, that proponents require stability in the planning and approval process and that this need must inform the decisions on timing of updates to the process or coefficients.

- Wind erosion from agricultural activities and construction sites has not been considered in the subwatershed modeling work completed to date and may contribute to the atmospheric deposition portion of loading to Lake Simcoe in both the pre-development (agricultural) and post-development (construction) phases. Many practices that reduce wind erosion potential may also reduce soil loss due to stormwater runoff. Therefore, future efforts should be made to quantify a) losses due to wind erosion from agricultural and construction activities, and b) the benefits of BMPs to reducing both types of soil loss.

- There is a need to account for changes in understanding of watershed processes or better estimates of phosphorus loads from specific land uses and to incorporate advances in storm water management, LID and BMPs as they are made available in the future. These could be accommodated by issuing addenda to the guidance document with updated phosphorus removal efficiencies for BMPs as they became available and were accepted by the MOE. These addenda would provide information requirements, rationale and criteria for adoption of new technologies and techniques. The modular approach of the Tool allows addenda to be issued for specific modules without the need to re-write the entire guidance document.

- There is a need to provide rationale and criteria to guide proponents who wish to consider alternative approaches and those who must review alternative approaches. This Guidance provides a generic methodology for quantifying phosphorus loading that is based on a set of assumptions used in an aggregated modeling approach. It makes generalizations about soil loss during construction phase and the efficiencies of a set

group of BMPs. Proponents may wish to undertake more detailed site modeling and/or monitoring to justify a development application under special circumstances. Such alternative approaches need to be considered to determine the appropriateness of the assessment to the specific site conditions.

- The Ministry may consider reviewing existing guidance for LID, Construction Phase activities (i.e., erosion and sedimentation considerations) and updating the SWMPD Manual from time to time to reflect current and emerging practices in these sectors.

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Appendix 1
Annotated Bibliography of Development BMPs Literature

Ref. #	Citation	*Reference*	Comments
1	Berger Group 2010	*Estimation of Phosphorus Loadings to Lake Simcoe.*	reviewed to establish phosphorus loading coefficients for the land uses in each of the Lake Simcoe subwatersheds
2	Toronto Region Conservation Authority 2006	*Erosion and Sediment Control Guidelines for Urban Construction*	this document focuses on sediment runoff mitigation for construction sites. The document does not quantify either percents or concentrations
3	Credit Valley Conservation 2010	*Low Impact Development Stormwater Management Planning and Design Guide CVC Version 1, 2010*	uses the treatment train approach to Low Impact Development. Ten techniques are described and runoff reduction estimates or TP reduction estimates are given for each LID technique
4	Schueler, T.R., 2000a	*Comparative Pollutant Removal Capability of Stormwater Treatment Practices Technical Note #95 from Watershed Protection Techniques. 2(4): 515-520.*	compares median % pollutant removal efficiencies for several stormwater treatment practices from the Centre for Watershed Protection database including: wet and dry ponds, wetlands, filters, infiltration, water quality swales and ditches - insufficient monitoring data to confidently assess performance of several commonly used practices, i.e. infiltration, bioretention, filter strips and swales
5	Schueler, T.R., 2000b	*Pollutant Removal Dynamics of Three Wet ponds in Canada Technical Note #114 from Watershed Protection Techniques. 3(3): 721-728.*	removal efficiencies and design details reported in this document are also presented in Reference #6 along with those of other Ontario stormwater treatment practices monitored under the SWAMP program
6	MOE et al 2005, SWAMP	*Synthesis of Monitoring Studies Conducted Under the Stormwater Assessment Monitoring and Performance Program*	provides evaluation of four wet ponds (including the 3 ponds in Reference #5), one wetland, one flow-balancing system, one underground tank and two oil grit separators in Ontario. Provides an overview of stormwater management practices and guidelines in Ontario, maintenance considerations, monitoring designs, and operational costs. Performance evaluations in the report are more relevant to the Lake Simcoe watershed than those reported for similar systems in the US (References #4, 7 and 9). The report is therefore the recommended prime source of information for these stormwater treatment practices.
7	Winer, R., 2000	*National Pollutant Removal Performance Database for Stormwater Treatment Practices 2nd Edition March 2000. Report prepared for the EPA Office of Science and Technology*	performance results of stormwater treatment practices in the US from 135 studies contained in the database - as % removal efficiencies and effluent concentrations (no influent concentrations are reported). Specific site or design characteristics are not considered. Contains a bibliography for more detailed site and design information. This is the detailed report summarized in Reference #4. All primary findings from the report are noted in the review of Reference #4 above.
8	Ontario Ministry of the Environment, 2003	*Stormwater Management Planning and Design Manual, 2003 and Ministry Guideline: Erosion and Sediment Control Best Management Practices (December 2006)*	guidance for the selection and sizing of stormwater management infrastructure with information on cost and maintenance for each technology. Reference for describing those types of stormwater mitigation technologies that are known for use in Ontario climates. no performance details given. Some references to the fact that certain techniques under certain conditions will export no water from the watershed to the receiving water

Ref. #	Citation	*Reference*	Comments
9	*http://www.bmpdatabase.org*	*The International Stormwater Best Management Practices (BMP) Database Project website*	provides access to the downloadable MS Access database as well as summary reports. allows downloading information summaries for each practice study using specified criteria (facility type, state/province, water quality parameters) that include design details, site characteristics and monitoring results. useful to refine performance evaluations for specific practices.
10	Mary T. Nett1, Mark J. Carroll, Brian P. Horgan, A. Martin Petrovic, 2008 American Chemical Society Volume 997, September 12, 2008	*Fate of Pesticides and Nutrients in the Urban Environment.*	empirical dataset based on measurements taken in an urban watershed in Ithaca, NY. The study was limited to 3 types of urban land use, Forested urban, general urban and fertilized lawns. Outcomes were useful only in a descriptive manner because load differences were not significant between land use types unless precipitation and runoff characteristics met certain conditions. General export coefficients that are divided between dissolved and particulate fraction may have some use for comparison. these types of data are rare therefore tabulated
11	Dr. John Sansalone of the Dept. of Environmental Engineering Sciences at the Univ. of Florida. February 2009	*TARP Field Test Performance Evaluation of Sorbtive Filter using Sorbtive Media for Imbrium Systems Corporation*	very detailed and contains conclusive evidence with respect to both solids and P removal efficiencies for a single active sorbtive media stormwater treatment system The system monitored removed 78% of TP with 12% confidence limits
12	LSRCA	*Black River, East Holland River, West Holland River, Uxbridge Brook, Maskinonge River subwatershed Plans*	provide projected phosphorous loadings under subwatershed development scenarios. Berger 2010 provide projections of development phosphorous loading based on the 2010 modelling data - also provides details that characterize the land uses in each subwatershed pertinent to phosphorus loading - details provided in these reports are useful for assessing the conditions of development sites that could contribute to phosphorus loading in the subwatershed

Appendix 2
Table of Construction Phase BMPs, Descriptions and Efficiencies

Description	Beneficial Management Practice (BMP) Category	Addresses what Loading Source?	Applicable to what site features?	Known Limitations of BMP	Reported Efficiency	Efficiency References (see Appendix 7)	Efficiency to Use
Anionic Polymer Runoff Treatment - flocculation and or coagulation of fine particles using polymers for the clarification of construction runoff to enhance downstream detention practices.	Runoff capture	Surface Runoff	Interior site	Requires proper design and monitoring to ensure that floc or polymer-dosed water does not get released to the environment	TSS = 88 to 94% (mean = 91%) with TSS influent concentration of 171 to 706 mg/L	41	91%
Bioretention Systems - biologic activity to filter/clean stormwater (infiltration basins, rainwater gardens, surface sand filters)	Filtration Systems	Surface runoff	Interior site	Can't treat large drainage areas, susceptible to clogging, consume a large area, high cost	TSS = 95% (45cm) TP = -1552-80	8-10, 12, 13, 34-38, 40	Site and design specific
Check Dams- permanent or temporary barrier that present erosion and promote sedimentation by slowing flows and filtering	Soil erosion control	Surface runoff		Requires periodic repair and sediment removal, removal can be expensive and difficult			Not available
Construction Phasing - creating a specified work schedule that coordinate the time of land-disturbing activities and the installation of erosion and sedimentation control measures to minimize the area and duration of exposed soil	Construction practices		Interior site, Stream, Drainage Channels	Requires more complex planning; potentially more costly as grading in done in multiple steps	TSS= 40%	112, article 54	Site specific
Dry Detention Ponds - collects stormwater runoff and store temporarily until infiltration and evaporation can occur	Detention Systems	Surface runoff	Interior site	For drainage areas greater than 10 acres, clogging, marginal removal of pollutants, unattractive, collect trash and debris	TSS = 61% TP = 0-20% Soluble P = -11%	104, 109	10%
Flow Splitters - restricts stormwater flows and creates bypass around the exposed areas	Flow Control Structures	Surface runoff	Interior site	Can create flow reversal, only for small systems			Site specific

Description	Beneficial Management Practice (BMP) Category	Addresses what Loading Source?	Applicable to what site features?	Known Limitations of BMP	Reported Efficiency	Efficiency References (see Appendix 7)	Efficiency to Use
Inlet Protection- prevention methods around storm drains limiting the amount of sediment entering the unit (sediment filter, sand bag barrier, geotextile barrier, compost biofilters, etc)	Filtration Systems	Impervious areas	Interior site	Needs to be properly maintained, not as effective for find-grained sediments or large loads; compost biofilters increase in efficiency with increased number of rolls used	TSS = 69% (for 5 rolls each 45cm diameter compost biofilters	114	69%
Maintenance - maintaining the BMPs that you currently have in place	House-keeping techniques	House-keeping	Entire site	Expensive, needs to be done somewhat frequently			Site specific
Mulches and Fibre or Geotextile Blankets and Mats - the application of organic materials, blankets or mats to form a temporary protective soil cover	Soil erosion control	Exposed soil, surface runoff	Interior site, Stream, Drainage Channels	Must be installed properly to be effective, mulching may not be effective on slopes greater than 3:1	29% - 99% TSS reduction (median = 90%) for various natural mulches and fiber blankets on slopes between 9% and 34% with various soils	112	90%
Pavement Management - cleaning streets and construction areas (sweeping, minimizing sand and salt applications, etc)	Housekeeping techniques	Impervious areas	Interior site				Site specific
Silt Fences - temporary barrier to retain sediment along the perimeter and watercourses on a construction site	Filtration Systems	Stockpiling, watercourse and perimeter protection	Stream, Site perimeter, Stockpiles	Not always effective, proper installation is crucial, maintenance and inspection is required frequently, poor efficiency with fine particles	TSS = 70% (median)	112, article 56	70%

Description	Beneficial Management Practice (BMP) Category	Addresses what Loading Source?	Applicable to what site features?	Known Limitations of BMP	Reported Efficiency	Efficiency References (see Appendix 7)	Efficiency to Use
Soakaways-Infiltration Trenches - area to capture stormwater runoff, retain it, and then infiltrate it into the ground over a period of days	Infiltration Systems	Surface runoff	Interior site	Potential high failure if not designed properly, possible groundwater contamination, not for high sediment/polluted areas, cannot use in industrial areas, requires large flat area, maintenance, inspection	TSS = 95% TP = 50-70% Soluble P = 51%	6, 104	60%
Structural Methods - installation of inlet/outlet riprap, permanent diversion, temporary diversions	Soil erosion control	Stream and watercourse runoff	Stream, Drainage Channels	Removal of temporary diversion structures can be expensive and time consuming			Site and design specific
Vegetative Filter Strips/Stream Buffers - maintain densely vegetated, uniformly graded areas that treat sheet flow from adjacent impervious surfaces	Filtration Systems	Surface runoff	Interior site	Can't use in hilly areas, difficult to monitor effectiveness, can use in contaminate areas, large area required, ineffective if improperly graded	TSS=70% TP = 60-70%	6, 42, 104	65%
Vegetative Methods - vegetative stabilization on site to prevent erosion, e.g., temporary seeding, sod	Soil erosion control	Exposed soil, surface runoff	Interior site, Stream, Drainage Channels	Cannot be implemented during off-seasons. In the fall heavy mulches will be used instead of vegetation.	99% TSS reduction (biomass at 2464 lb/acre compared to zero.)	113	99%
Vehicle Tracking Pad - entrance pad at construction access locations reduces the amount of mud transported onto paved roads by vehicles or surface runoff	Construction practices	Surface runoff	Interior site	Some sites will require extensive maintenance, some pads can become quickly saturated and plugged reducing effectiveness	Not available		Site specific

Description	Beneficial Management Practice (BMP) Category	Addresses what Loading Source?	Applicable to what site features?	Known Limitations of BMP	Reported Efficiency	Efficiency References (see Appendix 7)	Efficiency to Use
Wet Detention Ponds - stormwater pond with permanent pool. Provides peak flow control and water quality treatment	Retention Systems	Surface runoff	Interior site	For drainage areas greater than 10 acres, high cost, large area required, engineered design required, warm water discharges. Less effective on fine soils	TSS = 80% TP = 42-85% Soluble P = 66%	104-106, 109	63%

Appendix 3
Database Tool Users Manual

Hutchinson
Environmental Sciences Ltd.

Phosphorus Budget Tool in Support of Sustainable Development for the Lake Simcoe Watershed

Database User's Manual

Prepared By: **Stoneleigh Associates Inc.**
Prepared For: **Ontario Ministry of the Environment**

Project #: J110008
Date: March 30, 2012

Using the Lake Simcoe Phosphorus Loading Database Tool

Introduction

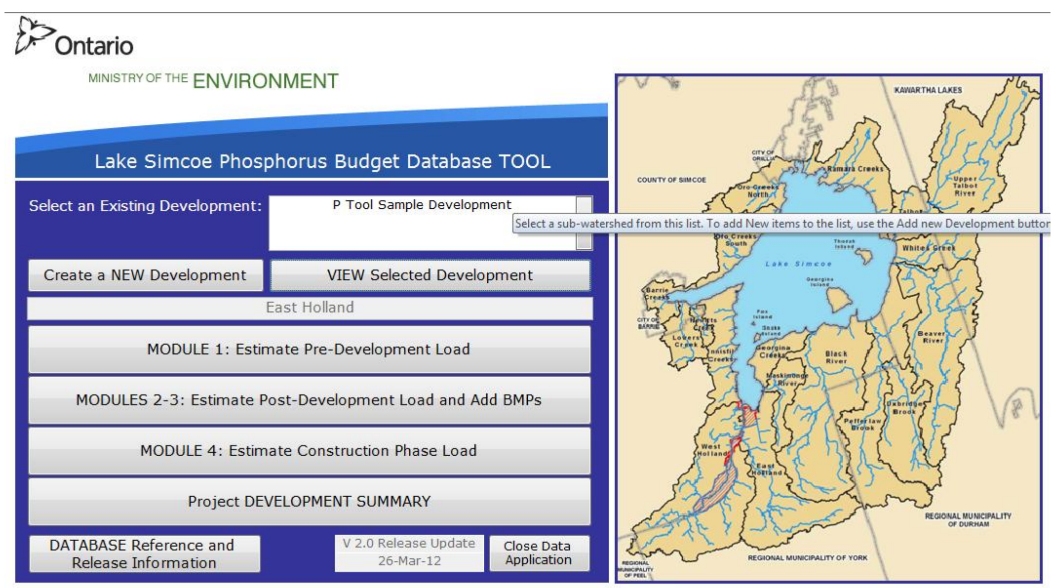
The "*Phosphorus Budget Guidance Tool to Guide New Development in the Lake Simcoe Watershed"* (the "Tool"; HESL, 2012) is intended for use by the development community, municipalities, the Ministry of Environment (MOE) and the Lake Simcoe Region Conservation Authority to facilitate review of major new development applications for their compliance with Policy 4.8e of the Lake Simcoe Protection Plan. The Tool provides a transparent and technically-sound approach to estimate phosphorus (P) loading from stormwater runoff in the pre-, post- and construction phases of development in the Lake Simcoe watershed. The Tool consists of three elements:

1. A **Technical Guidance Manual** that provides the reference material used in developing the Tool, the rationale for the development of the Tool, and implementation guidance in line with Policy 4.8e of the LSPP,
2. A **Microsoft ACCESS© Database Tool** that facilitates the calculation of a phosphorus budget for new development in accordance with the technical guidance, and
3. A **Database User's Manual** explaining the operation of the database.

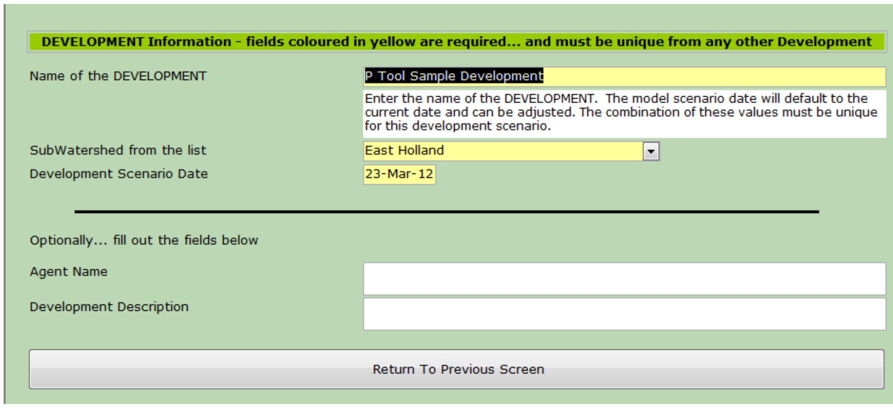
The following Database User's Manual provides step-by-step instructions to navigate the Database Tool. It is included as Appendix 3 of the Technical Guidance Manual of the Tool and is not intended as a "stand alone" description of the Tool or the estimation process, but rather as a set of instructions for operating the Microsoft ACCESS© Database Tool. ***The user must always rely on the Technical Guidance Manual as the primary technical source for instruction***.

Instructions

- Save the database file to any folder. All support reference data tables are warehoused within this single file.
- The database opens to a main screen. All features of the database are accessed from this opening view. The version code and date are displayed in the lower portion of this screen and cannot be adjusted by users.

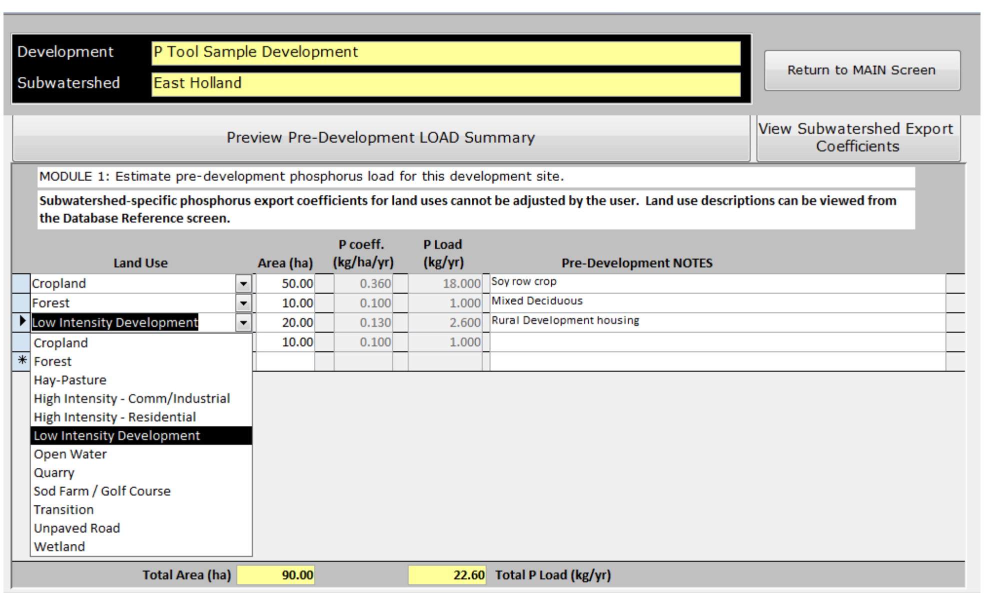


- To model a new development, the user will first need to enter information about the development. A unique development name, sub-watershed and date combination are required as input. Other optional information includes the developer or agent name and a description of the development.

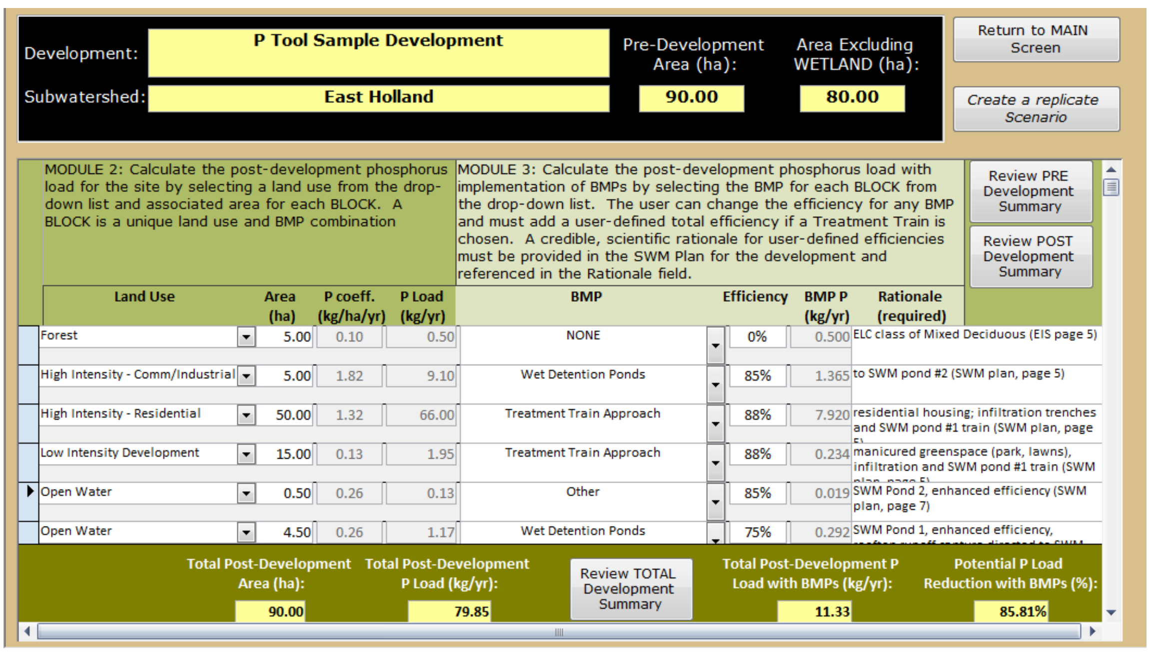


- The modules of the Tool are completed in sequence as information is entered for the pre-development, post-development and construction phase scenarios.

- MODULE 1: Pre-development conditions are entered by the user as displayed with the screen below. Users must have entered a new development or selected a previously entered development using the drop-down box on the main screen before they will be able to gain access to this screen. The landuse drop-down list options are contained in a reference table along with subwatershed-specific P export coefficients. The user must select a land use classification from among the options presented. The export coefficients are populated automatically by the tool and may NOT be adjusted by the user. A listing of all sub-watershed P export coefficients can be viewed from this screen by selecting the View Subwatershed Export Coefficients tab. After users enter the area values for each land use (to the nearest hundredth of a hectare) and press the tab key to advance to the notes field, the P load in kg/year is derived automatically. The total area of the development site is also derived automatically along with a total P load for the site and is displayed at the bottom of the screen. The user must verify that the total development area displayed is the same as in the development plan. A summary of the pre-development conditions can be viewed using the button provided. A sample summary report is shown in the Appendix of this document.



- MODULE 2: Post-development conditions can be added only after pre-development conditions have been entered in Module 1 (a blank screen will appear if this is not the case). The user must have also selected the development for which pre-development conditions were entered using the drop-down box on the main screen to display the information screen for Module 2. The name and total area of the development is displayed at the top of the screen. This information may not be adjusted, and displays and updates automatically. In the lower part of the screen, the user selects a land use from the drop-down menu and enters the area of that land use (to the nearest hundredth of a hectare) for each post-development block. The user must select a land use classification from among the options presented. The export coefficients are populated automatically by the tool and may NOT be adjusted by the user. A block is a unique combination of a land use and a specific Best Management Practice (BMP) that will be applied to that land use in Module 3. If the pre-development scenario in Module 1 contained wetland, it will automatically display on this screen and may not be altered by the user, under the assumption that development of wetlands is not approved in the Lake Simcoe watershed. The P export coefficient for each land use is a default value that is automatically entered from the lookup table and may not be adjusted.



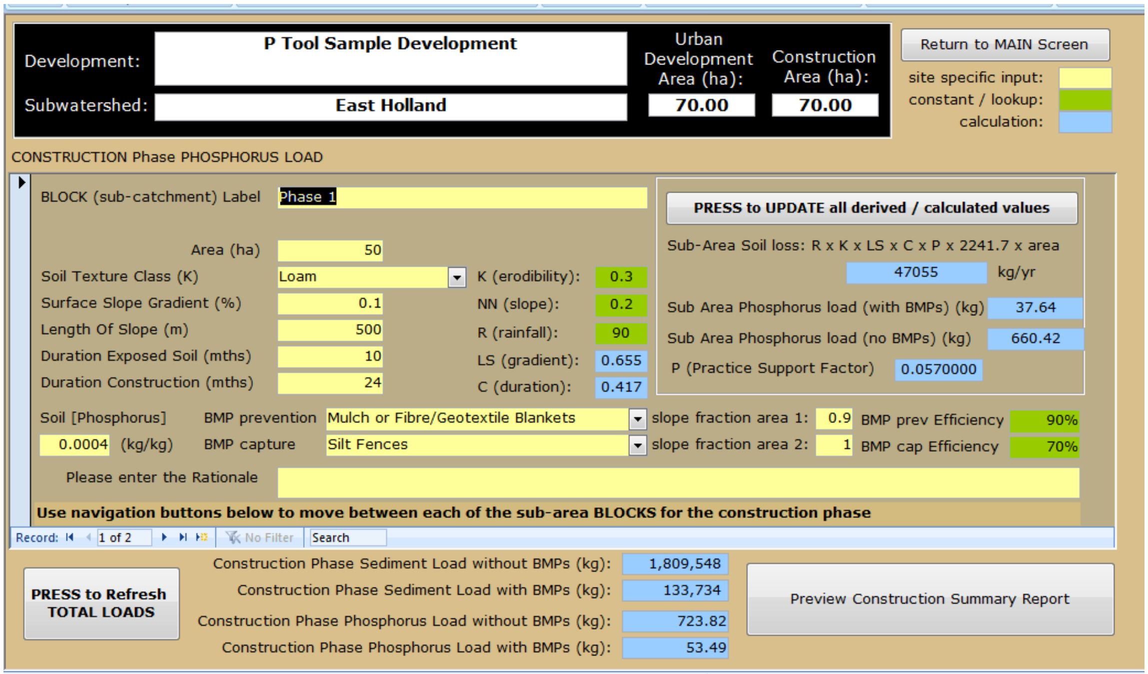
- MODULE 3: This step entails the selection of a BMP from the drop-down list for each post-development block. Some BMPs have defined P removal efficiencies whereas others do not. Percent efficiency values for the selected BMPs will be automatically displayed in the Efficiency field, but can be adjusted by the user. A BMP cannot be applied to wetlands. If a treatment train approach is selected from the drop-down menu, then the user must enter the total P removal efficiency for the approach. If different efficiency values for a specific BMP, a different BMP or a treatment train approach are provided by the user, credible scientific research and rationale in support of those value(s) or approach must be documented in the Stormwater Management (SWM) Plan for the development. The use of “custom” BMPs and efficiencies means that the application will be subject to a greater degree of review by the approving agency or agencies and so may require more time to assess. If users select “Other” or “Treatment Train” as a BMP, or adjust the pre-defined efficiency value, they will be prompted to enter a rationale. A brief rationale can be entered to the rationale field (up to 255 characters may be typed), but it should only provide a summary, and should refer the reviewer to the Stormwater Management (SWM) Plan for the full technical justification. Any change in the efficiency value from the base reference value provided will be reflected in the

Post-Development Summary report. Both the base reference efficiency and the user-adjusted value will be displayed along with an information note. A summary of the total development can be produced from this page using the button located at the middle of the bottom of the screen. Construction phase data will be displayed on the summary if it has previously been entered in Module 4. A sample summary report is shown in the Appendix of this document.

- Multiple scenarios of the same development area can be created to compare P loads with different combinations of post-development land uses and BMPs. A procedure to create a replicate scenario can be executed using the button marked 'Create a replicate scenario' at the top right of the screen (and shown below). A new Development will be created (and the message below will be displayed) when this button is pressed. The name of the replicated development will be the same as the one that the user has selected with a suffix added containing the words '-replicate scenario' followed by a data and time stamp. This enables users to create multiple replicates on the same day to assess different BMP scenarios. Users can adjust the name of a replicate scenario by returning to the main screen, selecting it from the drop-down list, then selecting 'VIEW Selected Development' tab. Adjustments to the post-development information will also be required to distinguish the replicate scenario from the original.

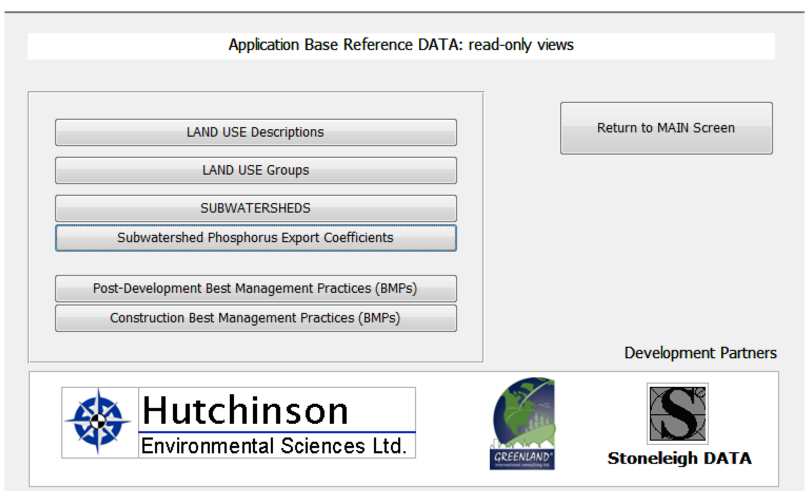
- MODULE 4: Construction phase information can be added only after pre-development conditions have been entered in Module 1(a blank screen will appear if this is not the case). The user must have also selected a development using the drop-down box on the main screen to display the information screen for Module 4. The following screen illustration shows both the total urban development and construction area at the top of the screen. These values may not be adjusted and are displayed automatically. There may be some delay in the update of the construction area value as users enter information for each construction block. A construction phase block is a subarea of the development site with relatively uniform slope and soil conditions where one prevention and one capture BMP, or one treatment train will be applied. There is no limit to the number of blocks in each construction development.

  - Using the lower part of the screen, enter the values shaded in yellow. Values in green will be entered as either constants or filled in automatically from reference lookup tables in the database. Fields shaded in blue are derived by the database using the formulae described in the Guidance Manual.
  - Enter the required input values for each construction phase block. Each block can be accessed using the record selectors at the bottom of the inner construction phase data field. The derived values will update automatically as new values or entered or changed.
  - The user can adjust the pre-defined BMP efficiency values, but must provide a credible scientific rationale for doing so in the SWM plan for the development. A brief rationale can be entered in the field provided.
  - A summary of the Construction Phase site sediment loss and P export can be viewed using the button labelled "Preview Construction Summary Report" provided at the lower right of the screen. A sample summary report is shown in the Appendix of this document.



- An overall summary of each Module can be displayed using the button on the main screen marked ‘Project Development Summary’. This summary includes each of the four module summary reports and a final conclusion about P load reduction or increase as a result of development and construction activities. A sample “Project Development Summary” report is provided in the Appendix of this document.

- Base reference data used in the model calculations can be viewed by clicking the button marked ‘Database Reference and Release Information’. All data from these views are read-only and may not be adjusted by the user.



APPENDIX A: Sample Summary Reports

A1 – Pre-Development Report
A2 – Post-Development Report
A3 – Construction Phase Report
A4 – Summary Report

A1 – Pre-Development Report

Ontario
MINISTRY OF THE ENVIRONMENT

Database Version: V 2.0 Release Update
Update Date: 28-Mar-12

PRE-DEVELOPMENT Phosphorus LOAD

DEVELOPMENT: **P Tool Sample Development**
Subwatershed: **East Holland**

Land Use	Area (ha)	P coeff. (kg/ha)	P Load (kg/yr)
Cropland	50	0.36	18.00
Forest	10	0.10	1.00
Low Intensity Development	20	0.13	2.60
Wetland	10	0.10	1.00
TOTALS:	**90**		**22.60**

March-28-12

Page 1 of 1

A2 – Post-Development Report

Ontario

MINISTRY OF THE ENVIRONMENT

Database Version: V 2.0 Release Update
Update Date: 28-Mar-12

POST-DEVELOPMENT Phosphorus LOAD - BMPs applied

Subwatershed: East Holland

Land Use	Area (ha)	P coeff. (kg/ha)	Best Management Practice applied with P Removal Efficiency		BMP P Load (kg/yr)
DEVELOPMENT:	**P Tool Sample Development**				
Forest	5	0.10	NONE	0%	0.50
			ELC class of Mixed Deciduous (EIS page 5)		
High Intensity - Comm/Industrial	5	1.82	Wet Detention Ponds	**85%**	1.36
			to SWM pond #2 (SWM plan, page 5)		
NOTE: BMP efficiency has been adjusted from the reference provided value by 22% (from 63% to 85%)					
High Intensity - Residential	50	1.32	Treatment Train Approach	88%	7.92
			residential housing; infiltration trenches and SWM pond #1 train (SWM plan, page 5)		
Low Intensity Development	15	0.13	Treatment Train Approach	88%	0.23
			manicured greenspace (park, lawns), infiltration and SWM pond #1 train (SWM plan, page 5)		
Open Water	4.5	0.26	Wet Detention Ponds	**75%**	0.29
			SWM Pond 1, enhanced efficiency, rooftop runoff capture directed to SWM (SWM Plan, page 6)		
NOTE: BMP efficiency has been adjusted from the reference provided value by 12% (from 63% to 75%)					
Open Water	0.5	0.26	Other	85%	0.02
			SWM Pond 2, enhanced efficiency (SWM plan, page 7)		
Wetland	10	0.10	NONE	0%	1.00
			cannot be altered		

Post-Development Area Altered: **90.00**

Total Pre-Development Area: **90.00**

Unaffected Area: **0**

	P Load (kg/yr)
Pre-Development:	**22.60**
Post-Development Load:	**79.85**
Change (Pre- Post):	**-57.25**
	253% Net Increase in Load
Post-Development (with BMP):	**11.33**
Change (Pre-Post):	**11.27**
	49.86% Net Reduction in Load

March-28-12 Page 1 of 1

A3 – Construction Phase Report

Database Version: V 2.0 Release Update
Update Date: 28-Mar-12

Ontario
MINISTRY OF THE ENVIRONMENT

CONSTRUCTION Site Sediment and Phosphorus LOAD

DEVELOPMENT: **P Tool Sample Development**
Subwatershed: **East Holland**

Site Specific input: | constant / lookup: | *calculation:*

Sub Area: Phase 1

Duration of Construction (months):	24	R (Rainfall / Runoff for Lake Simcoe)	90
Duration of Exposed Soil (months):	10	K (Soil erodability factor):	0.3
Surface Slope Gradient (%):	0.1	NN (determined by slope):	0.2
Length Of Slope (m):	500	BMP prevention Efficiency:	90%
Slope Area (ha):	50	BMP capture Efficiency:	70%
% slope erosion prevention applied to:	0.9	LS (slope length gradient factor):	*0.65*
% slope runoff capture applied to:	1	C (portion of year of exposed soil):	*0.42*
subwatershed Soil [P] (kg/kg):	0.0004	P (prevention + capture):	*0.06*
		Soil Loss (kg/year):	*47054.96*
		Phosphorus load (kg):	*37.64*

Sub Area: Phase 2

Duration of Construction (months):	12	R (Rainfall / Runoff for Lake Simcoe)	90
Duration of Exposed Soil (months):	4	K (Soil erodability factor):	0.18
Surface Slope Gradient (%):	0.1	NN (determined by slope):	0.2
Length Of Slope (m):	250	BMP prevention Efficiency:	75%
Slope Area (ha):	20	BMP capture Efficiency:	60%
% slope erosion prevention applied to:	0.5	LS (slope length gradient factor):	*0.65*
% slope runoff capture applied to:	1	C (portion of year of exposed soil):	*0.33*
subwatershed Soil [P] (kg/kg):	0.0004	P (prevention + capture):	*0.25*
		Soil Loss (kg/year):	*39624.27*
		Phosphorus load (kg):	*15.85*

Developed AREA (ha): 70

	Total
Construction Phase Phosphorus Load with BMPs (kg):	53.49
Construction Phase Phosphorus Load no BMPs (kg):	723.82

March-28-12 Page 1 of 1

A4 – Summary Report

DEVELOPMENT: P Tool Sample Development
Subwatershed: East Holland

SUMMARY WITH IMPLEMENTATION OF BMPs	P Load (kg/yr)
Pre-Development:	**22.60**
Construction Phase Amortized Over 8 Years :	6.69
Post-Development:	**11.33**
Post Development + Amortized Construction:	**18.02**
Pre-Development Load - Post-Development Load:	**11.27**
Conclusion:	**50% Reduction in Load**
Pre-Development Load - (Post-Development + Amortized Construction Load):	**4.58**
Conclusion:	**20% Reduction in Load**

Based on a comparison of Pre-Development and Post-Development loads, and in consideration of Construction Phase loads, the Ministry would encourage the Municipality to:

Approve development as site specific appropriate.

Appendix 4
Analysis of Berger (2010) Export Coefficients

Corrected Export Coefficients Derived from Berger P Loads and Land Use Areas

Phosphorus loads (kg/yr) from land use areas were adjusted by adding loads from:

1) **Groundwater** proportionally by area to all land use categories except High Intensity Development,
2) **Tile Drainage** to Crop areas, and
3) **Stream Bank Erosion** proportionally by area to Forest, Wetland and Transition areas

Groundwater loads were not allocated to High Intensity Development areas considering that these areas have a large amount of impermeable surfaces, thereby reducing groundwater loads. Stream Bank Erosion was only allocated to 'natural' land cover areas assuming that streams primarily occur in these land areas. Refined land use data would be required to determine the proportion of P loads from stream bank erosion in other land class areas (e.g., proportion of streams running through agricultural area or urban area). The corrected loads were then used to calculate P export (kg/ha/yr) for each land use (Table 1).

As previously noted, there is considerable variance in P export coefficients among subwatersheds, but much of the variance occurs among unmonitored subwatersheds (Table 2, Figure 1). Export coefficients derived for the East Holland River (EH) subwatershed are higher on average than those for the other monitored subwatersheds (with the exception of LID, which is suspected as being an error and removed from Table 2 and Figure 1 results). Variance in export coefficients for the monitored subwatersheds is greatly reduced when EH coefficients are removed however, there is still considerable variance in export coefficients among monitored subwatersheds for Turf-Sod and Unpaved Road.

Variance in export coefficients was further assessed using Principal Component Analysis (PCA) (Figure 2). The first two axes of the PCA explain 94% of the variation in export coefficients for land cover classes between the subwatersheds. The first PCA axis is best described by variation in export coefficients for Unpaved Roads (UNPAV) and the second axis is best described by variation in export coefficients for High Intensity Development (HID) and Cropland (CROP). Hay/pasture (HAY_PAST) and Quarry (QU) contribute nearly equally to the variation along the first and second PCA axes. Contribution of the other land cover classes to the variation explained by the first and second PCA axes is negligeable. Overall, the results of the PCA indicate that the East Holland River River (EH), Oro Creeks North (ON), Hawkestone (HA), Barrie Creeks (BA) and Georgina Creeks (GE) differ from the other subwatersheds by having higher export coefficients for UNPAV, HID, CROP, HAY_PAST and QU.

Table 1. Phosphorus Export Coefficients (kg/ha/yr) for Land Cover Types in the Lake Simcoe Subwatersheds

no value
GW inputs only

Subwatershed	Phosphorus Export (kg/ha/yr)									
	Cropland	Forest	Hay-Pasture	High Intensity Develop-ment	Low Intensity Develop-ment	Quarry	Transition	Turf-Sod	Unpaved Road	Wetland
East Holland	0.357	0.100	0.116	0.659	0.013	0.530	0.161	0.243	3.715	0.099
Beaver River	0.218	0.022	0.040	0.381	0.193	0.063	0.040	0.014	0.049	0.020
Black River	0.229	0.045	0.075	0.393	0.167	0.152	0.057	0.023	0.598	0.044
Hawkestone Creek	0.185	0.031	0.097	0.254	0.089	0.098	0.036	0.061	2.394	0.026
Lovers Creek	0.164	0.060	0.071	0.237	0.067	0.063	0.064	0.168	0.015	0.053
Pefferlaw-Uxbridge Brook	0.109	0.034	0.055	0.206	0.131	0.041	0.044	0.022	0.413	0.035
Whites Creek	0.226	0.096	0.103	0.286	0.149		0.113	0.424	0.682	0.094
Barrie Creeks	0.887	0.182	0.231	1.802	0.102	0.066	0.213		0.050	0.179
Georgina Creeks	0.598	0.018	0.498	1.048	0.013		0.122	0.633	1.152	0.016
Hewitts Creek	0.272	0.182	0.090	0.253	0.057		0.161		1.046	0.062
Innisfil Creeks	0.379	0.086	0.086	0.431	0.103	0.587	0.096	0.124	0.638	0.082
Maskinonge River	0.188	0.121	0.091	0.339	0.118	0.210	0.132		0.241	0.121
Oro Creeks North	0.953	0.049	0.619	1.696	0.060	1.348	0.231		2.911	0.040
Oro Creeks South	0.137	0.041	0.036	0.207	0.020		0.049	0.020	0.217	0.041
Ramara Creeks	0.309	0.052	0.048	0.103	0.043		0.056	0.237	0.217	0.048
West Holland	0.255	0.105	0.065	0.245	0.042	0.206	0.108	0.393	0.573	0.103

Table 2. Summary of Phosphorus Export Coefficients for the Lake Simcoe Watershed Derived from Berger (2010)

Phosphorus Export (kg/ha/yr)										
	Cropland	Forest	Hay-Pasture	High Intensity	Low Intensity	Quarry	Transition	Turf-Sod	Unpaved Road	Wetland
All Subwatersheds										
Mean	0.341	0.075	0.147	0.525	0.095	0.283	0.101	0.210	0.856	0.064
Maximum	0.953	0.182	0.619	1.802	0.193	1.348	0.231	0.633	2.911	0.179
75th Percentile	0.344	0.101	0.100	0.412	0.127	0.209	0.127	0.354	1.046	0.088
Median	0.229	0.052	0.086	0.286	0.095	0.125	0.096	0.146	0.598	0.048
25th Percentile	0.186	0.038	0.060	0.241	0.058	0.064	0.052	0.033	0.241	0.038
Minimum	0.109	0.018	0.036	0.103	0.013	0.041	0.036	0.014	0.049	0.016
Monitored Subwatersheds										
Mean	0.213	0.055	0.080	0.345	0.133	0.158	0.074	0.136	1.309	0.053
Maximum	0.357	0.100	0.116	0.659	0.193	0.530	0.161	0.424	3.715	0.099
75th Percentile	0.227	0.078	0.100	0.387	0.163	0.139	0.089	0.205	1.966	0.073
Median	0.218	0.045	0.075	0.286	0.140	0.081	0.057	0.061	0.640	0.044
25th Percentile	0.175	0.033	0.063	0.245	0.099	0.063	0.042	0.022	0.460	0.031
Minimum	0.109	0.022	0.040	0.206	0.067	0.041	0.036	0.014	0.049	0.020
Unmonitored Subwatersheds										
Mean	0.442	0.093	0.196	0.681	0.067	0.483	0.130	0.347	0.874	0.077
Maximum	0.953	0.182	0.619	1.802	0.118	1.348	0.231	0.633	2.911	0.179
75th Percentile	0.598	0.121	0.231	1.048	0.102	0.587	0.161	0.453	1.073	0.103
Median	0.309	0.086	0.090	0.339	0.058	0.210	0.122	0.315	0.606	0.062
25th Percentile	0.255	0.049	0.065	0.245	0.043	0.206	0.096	0.208	0.235	0.041
Minimum	0.137	0.018	0.036	0.103	0.013	0.066	0.049	0.124	0.217	0.016
Monitored Subwatersheds Excluding EH										
Mean	0.188	0.048	0.074	0.293	0.133	0.084	0.059	0.119	0.827	0.045
Maximum	0.229	0.096	0.103	0.393	0.193	0.152	0.113	0.424	2.394	0.094
75th Percentile	0.224	0.056	0.091	0.358	0.163	0.098	0.063	0.141	0.682	0.051
Median	0.202	0.040	0.073	0.270	0.140	0.063	0.050	0.042	0.598	0.040
25th Percentile	0.169	0.032	0.059	0.241	0.099	0.063	0.041	0.022	0.413	0.029
Minimum	0.109	0.022	0.040	0.206	0.067	0.041	0.036	0.014	0.049	0.020
East Holland										
P Export (kg/ha/yr)	0.357	0.100	0.116	0.659	-	0.530	0.161	0.243	3.715	0.099

Figure 1. Boxplots showing variance in export coefficients derived from Berger (2010) for the Lake Simcoe Subwatersheds. Boxes represent 25th percentile, median and 75th percentile, whiskers are the minimum and maximum values, and the mean is denoted as the black dot.

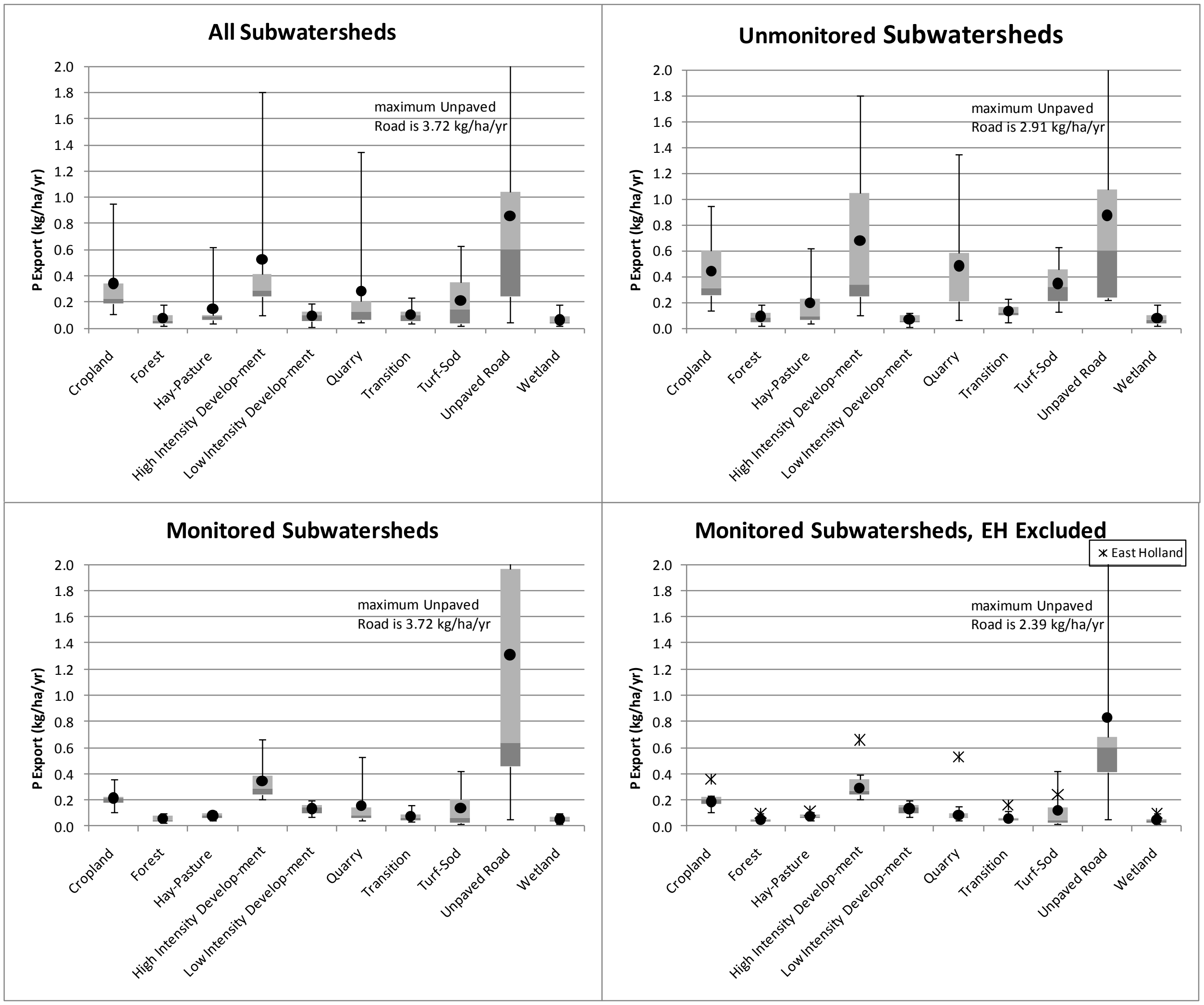
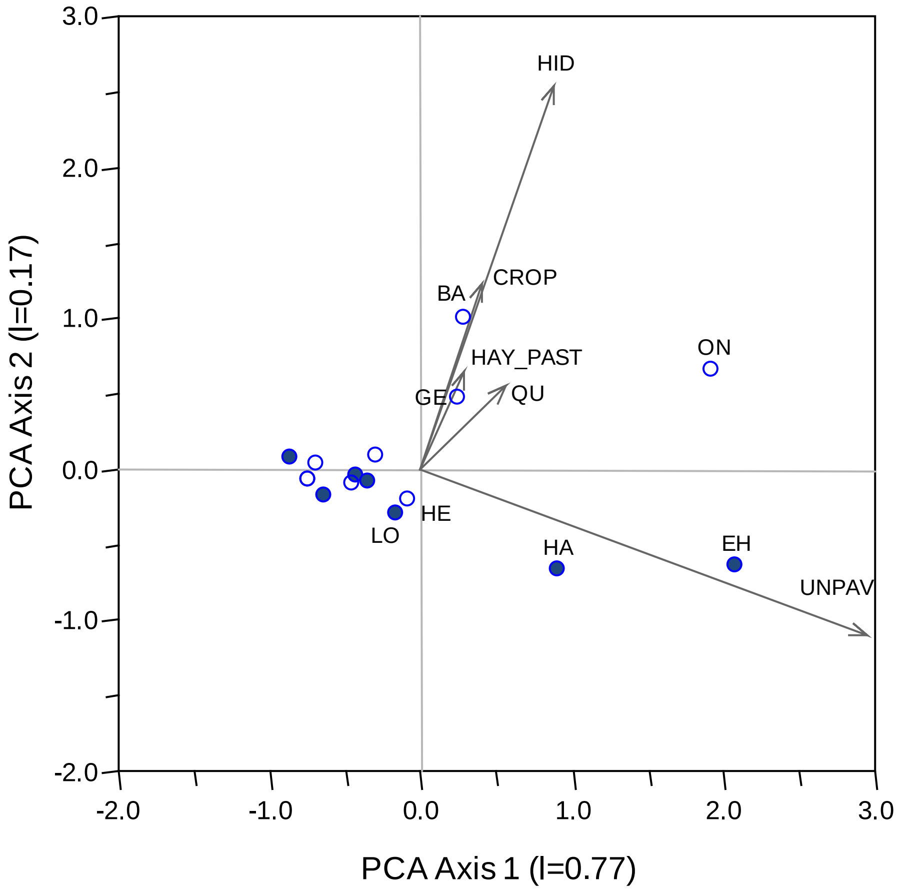


Figure 2. PCA of P export coefficients for land cover classes in Lake Simcoe subwatersheds. Solid circles indicate monitored subwatersheds.



Note: Factor arrows are not shown for Forest, Wetland, Transition, Turf-Sod or Low Impact Development as the contribution of these factors to the first two PCA axes is negligible.

Some variation in phosphorus export between subwatersheds is expected for a given land cover type due to differences in environmental factors such as soil characteristics and runoff conditions. The variation in P export coefficients for the Lake Simcoe subwatersheds was further investigated based on environmental factors used in the CANWET model. These included Soil K Factor (erosion coefficient), Slope Length, Base Runoff and Soil P as reported in Berger (2010) for each land cover type in each subwatershed.

In a PCA of the environmental factors, the first PCA axis describes 36% of the variation in the data set and is related to soil conditions (Soil P and Soil K Factor) (Figure 3). Slope length and base runoff best describe variation along the second axis, which describes 29% of the variation in the data set. It should be noted that the environmental factors for Quarry were eliminated from the PCA as these were strongly influenced by slope length and had a large influence on the ordination.

The centroids of the subwatersheds are separated primarily along the first PCA axis indicating that they differ along a gradient of Soil K and Soil P (increasing from left to right in the PCA biplot). The East Holland and West Holland subwatersheds are also characterized by higher base runoff in comparison to

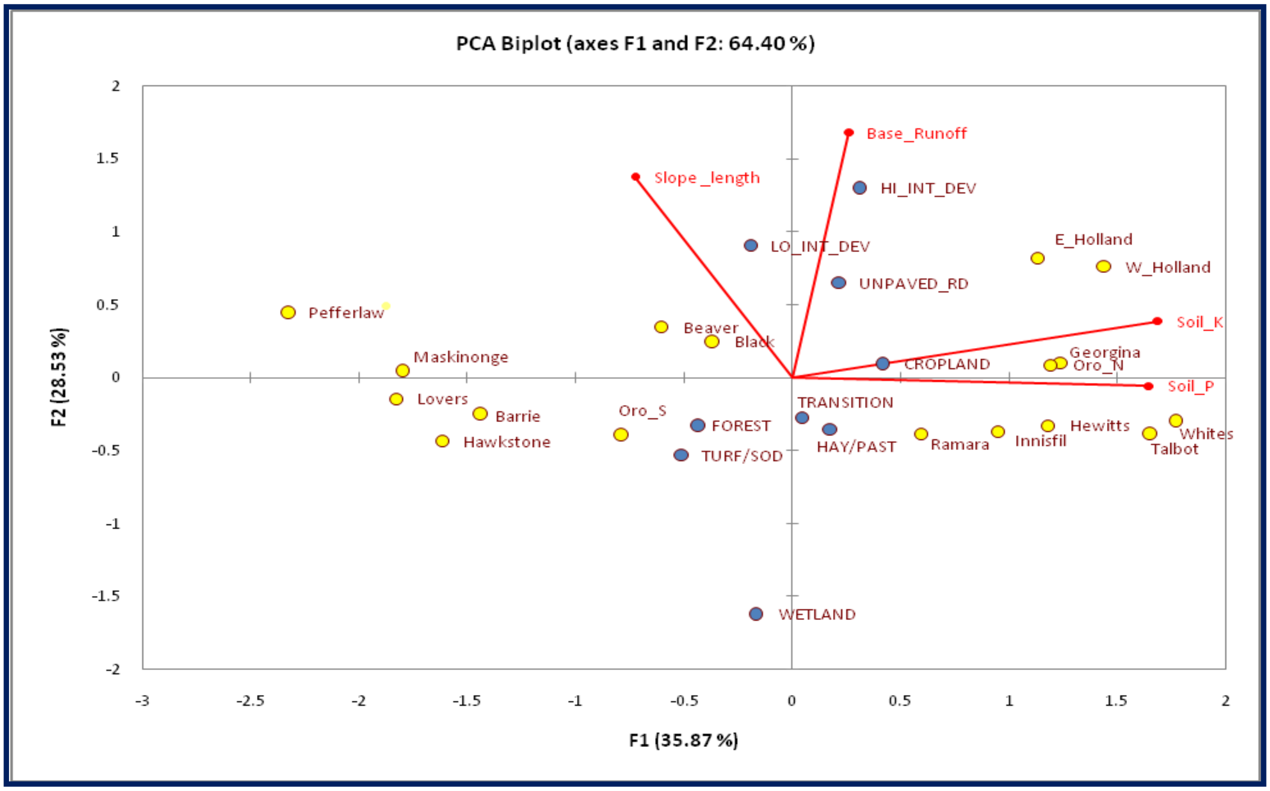
the other subwatersheds. Land cover types, by contrast, are separated primarily along the second PCA axis with High Intensity Development, Low Intensity Development and Unpaved Roads characterized by higher base runoff and greater slope length in comparison to the other land cover types.

As previously described, the East Holland River, Georgina Creeks and Oro North subwatersheds generally have higher export coefficients than the other subwatersheds. Centroids for these subwatersheds plot in the top right quadrat of the PCA indicating that they have generally higher soil K factors, Soil P and base runoff than the other subwatersheds, which would be consistent with higher P export. The West Holland River subwatershed plots in the same quadrat, however, export coefficients for this subwatershed are similar to the mean values.

Barrie Creeks subwatershed also had higher export coefficients, particularly for Cropland and High Intensity Development, but this subwatershed has environmental factors similar to other subwatersheds with comparatively lower export coefficients (i.e., Lovers, Maskinonge, Hawkestone).

Hawkestone subwatershed had high export coefficients for Unpaved Road and displayed relatively high slope lengths for this land cover class (not shown). Other subwatersheds had similarly high slope lengths for unpaved road areas, but did not have similarly high export (e.g., Pefferlaw, Lovers) for this land cover.

Figure 3. PCA biplot of environmental factors (n=4) for land cover classes in Lake Simcoe Subwatersheds (n=148). Yellow circles represent the centroids of the subwatershed sample scores while blue circles represent the centroids of the land cover type sample scores.



Summary and Recommendations

While patterns in the environmental factors appear to explain some variation in export coefficients, there is no clear, consistent relationship (e.g., weak correlations between environmental factors (actual values and PCA axis sample scores) and export coefficients) when considering both monitored and unmonitored subwatersheds. This may reflect complexities of data manipulation and calibration in CANWET or the use of other unknown coefficients or input parameters that influence phosphorus export in the model. In addition, there may be error in the allocation of phosphorus loads from groundwater, tile drainage and streambank erosion to the different land classes.

Despite the above uncertainties, the export coefficients derived for the monitored subwatersheds display little variability within land cover classes with few exceptions. The East Holland River has higher export coefficients relative to all other monitored subwatersheds, which is likely due to higher soil K Factors, soil P and base runoff of land cover areas in this subwatershed. For the remaining monitored subwatersheds, variation in export for unpaved roads is mainly due to high export from Hawkestone subwatershed which has very high slope length for this parameter in comparison to the other monitored subwatersheds. Similarly, the variability in turf/sod is mostly attributed to the high export coefficient for the Whites Creek subwatershed, which has higher soil phosphorus and a larger soil K factor than the other monitored subwatersheds (excluding the EH) for this land class.

Given the remaining uncertainty regarding variation in export coefficients within land classes among unmonitored Lake Simcoe subwatersheds, it is recommended that export coefficients from the monitored subwatersheds be used until additional information or data becomes available to better evaluate variation or to refine export estimates. One option is to apply the mean P export derived from the monitored subwatersheds excluding the East Holland River subwatershed to land cover areas of the unmonitored subwatersheds. P export coefficients from the EH subwatershed can be applied to unmonitored subwatersheds suspected of having higher export due to environmental conditions (i.e., West Holland, Georgina Creeks and Oro North).

Appendix 5
Responses to Comments from the Lake Simcoe Science Committee

Comment/Question	Report Reference	Disposition	Action
Add Winter et al., 2007 reference for urban land coefficients	pg. 6	Agreed	Citation and Reference added
Reword text describing Low Intensity Development and Unpaved Road coefficients	pg. 13	Agreed	Text reworded as recommended
Remove redundant text re. export coefficient uncertainties/error	Table 1, Appendix 4	Agreed	Redundant text removed from table
Recommendations for future directions related to policy amendments and the need to update the SWMPD Manual	general	The recommendations are noted, but are outside the scope of the project and may be considered in future updates of the P Budget Tool	Added " The Ministry may consider reviewing existing guidance for LID, Construction Phase activities (i.e., erosion and sedimentation considerations) and updating the SWMPD Manual from time to time to reflect current and emerging practices in these sectors." to Section 4 - Future Directions
Estimation of soil erosion through USLE is not intended for anything that may have significant channelized flow which is likely from a construction site; not certain how this is handled	pg. vi	We agree that USLE is appropriate for diffuse overland flow, not channelized flow. We stated that "The Tool addresses losses through surface runoff only." in Section 3.4.1 of the report.	None - concept is noted (Section 3.4.1) in the report
Do export coefficients vary between watersheds due to inherent differences in soils/landscapes/hydrology or because of location of the various land uses relative to flow paths to surface waters?	general	Export coefficients are expected to vary between watersheds for both reasons. Causes of expected variance between watersheds is discussed in Section 3.2.1.1	None - concept is noted (Section 3.2.2.1) in the report
K factor should be applied to exposed soil material and not necessarily what the top soil was/is.	general	Agreed	Changed definition to clarify application to exposed soils in Section 3.2.2 - "K is the soil erodibility factor based on soil textural class and organic matter content *of exposed soil..."*

Comment/Question	Report Reference	Disposition	Action
Studies have shown an enrichment factor in terms of the concentration of P in eroded sediments versus the bulk soil P content, i.e., the sediment/soil lost through erosion is enriched in P relative to the bulk soil. Is this considered in the tool?		This is considered in the CANWET model and therefore part of the pre- and post-development export coefficients. It was to be considered in the calculations for the construction phase through the use of subwatershed soil P values. However, due to the variability between subwatersheds it was decided that a single soil phosphorus value would be used globally in the watershed.	Added the following to Section 3.4.2 "Soil phosphorus concentration was originally intended to be a subwatershed value derived from the CANWET model. However, due to the variability between subwatersheds it was decided that a single soil phosphorus value would be used globally in the watershed. The CANWET model applies an empirical enrichment factor to the initial estimate of soil phosphorus to account for the greater phosphorus adsorption surface of smaller particles that make up a greater portion of eroded material."
Suggested taking a more conservative approach to derive export coefficients for undeveloped lands (i.e., lower export coefficient for undeveloped lands) using 30%ile rather than the mean to stimulate research	Section 3.2	We disagree with this approach as there is no scientific basis for using the 30th percentile or for prescribing a lower export from undeveloped lands only. While there is some error expected in the selected coefficients, these were calculated using a scientific approach with best available knowledge and are defensible. In recognition of possible site-specific differences in P export, we included an allowance to adjust the export coefficients as long as a detailed rationale is provided for consideration by the MOE.	None
What is the 20% adjustment allowance based on?	Section 3.2	The 20% adjustment allowance stems from previous drafts and discussions. This limited allowance has been eliminated and the User is able to adjust the coefficients with justification for site-specific characteristics. If so, a detailed rationale for the adjustment is required, including published references, for any adjustment (as entered by the user in a text box) for consideration by the MOE.	All references to 20% adjustment allowances have been removed from the text.

Comment/Question	Report Reference	Disposition	Action
Should specify the criteria required to satisfy the MOE for adjustments to the export coefficients	Section 3.2	Adjustments would be requested on a case by case basis and, in all cases, MOE would assess the request on its own merits.	None
Noted that efficiency of BMPs decline over time unless maintained and questions how the Tool deals with this.	Section 3.3	Agreed, BMPs are known to decline in P removal efficiency if not properly maintained. The document assumes that any BMP to be implemented will be maintained to ongoing standards. In Section 3.4.2, the manual states that: "In all cases there is a requirement that BMPs are maintained throughout the duration of the construction phase in order that they continually operate at their design efficiency."	Clarified assumption of BMP maintentance in Section 3.1.2.2 "...can be used, if built to design specification and maintained to design standards, with assurance of their effectiveness."
If a coefficient for a BMP reduction changes during design phase, what coefficient should apply to the Applicant	general	The applicant should ensure that the most recent version of the Tool is used for their application. It would be expected that the conditions of the MOE-approved application would apply for the duration of the development construction.	None

Appendix 6
BILD Comments and HESL Response to Technical Comments

HESL Responses to Technical Comments from BILD

BILD Comment: BILD noted the importance of atmospheric deposition to the total annual phosphorus load to Lake Simcoe and suggested that the manual "should acknowledge this issue and a commitment should be made by MOE to revise the model once the science of atmospheric deposition of phosphorous has been advanced".

HESL Response: We agree that changes in land use and BMP implementation to reduce phosphorus loading may reduce atmospheric loads to Lake Simcoe. As noted by BILD, however, the state of science is not presently sufficient to calculate the relative contribution of different land use practices to the atmospheric load. We have clarified this point in the report with the following statements:

- "The Tool does not address atmospheric sources of phosphorus in dust generated from land use practices, as the science is not yet advanced to the point where estimates can be made. It does account for atmospheric deposition of phosphorus to open water and atmospheric deposition to land surfaces is included in the export coefficients for various land use practices." (Executive Summary, page ii)

- "Note that phosphorus loads from atmospheric deposition to land are incorporated into the export coefficients for the various land cover classes. The atmospheric/open water coefficient should not be interpreted as loading from dust generated by land use activities such as agriculture or construction. It represents a regional atmospheric contribution. The means to estimate dust generation and loading are the subject of current research initiatives being undertaken by the MOE, the LSRCA and various research partners." (page 14)

Further, we have added a recommendation in Section 4 of the report that states:

- Wind erosion from agricultural activities and construction sites has not been considered in the subwatershed modeling work completed to date and may contribute to the atmospheric deposition portion of loading to Lake Simcoe in both the pre-development (agricultural) and post-development (construction) phases. Many practices that reduce wind erosion potential may also reduce soil loss due to stormwater runoff. Therefore, future efforts should be made to a) quantify losses from wind erosion from agricultural and construction activities and b) the benefits of BMPs to reducing both types of soil loss.

BILD Comment: BILD suggested a trial period for the Tool.

***HESL Response*:** We agree that a trial period would be useful to inform the process.

BILD Comment: Request for 'clear transition rules surrounding existing applications and approvals be outlined in the Budget Tool when it is posted to the Environmental Registry'.

HESL Response: This relates to MOE policy and should be addressed outside of the budget tool document.

BILD Comment: 'BILD members have identified concerns for the need to calculate phosphorus loading during the construction phase of a project.'

HESL Response: We included calculations to estimate construction phase phosphorus loads in the Manual using the best available information, as required by the project RfP. The Manual recognizes the difficulties in calculating construction phase loads, but is focussed on the use of BMPs to reduce these loads despite uncertainties in calculations.

BILD Comment: 'BILD members have expressed that the breakdown of the land use classifications is too detailed and requires the expertise of an ecologist to decipher. A number of sites do not require an environmental report which would make selecting the correct pre-development land use from the breakdown provided in the document difficult. BILD requests additional clarification and direction in this regard.

HESL Response: HESL notes that an Environmental Impact Study (EIS) should be done for all new major developments, which would include classification of land use areas. While an ecologist may be required to classify and delineate land uses, we suggest that this is good practice.

BILD Comment: 'BILD members are concerned that we may find ourselves in a situation where we have employed all of the practical Best Management Practices and Low Impact Development measures which support the reductions of phosphorous loading, but yet, we may still find ourselves in a shortfall when applying the Budget Tool. Since phosphorous trading is not yet available, our members request clarification as to whether or not the project would get rejected if this situation were to happen.'

HESL Response: This comment reflects policy decision that MOE will have to make. Our manual provides methods on how to make the calculations.

Appendix 7

References for BMP Phosphorus % Reduction Coefficients Shown in Table 3 and Appendix 2

Ref ID	Author	Year	Title	Publication
2	Van Seters et al.	2009	Referenced in: Low Impact Development Stormwater Management Planning and Design Guide - CVC Version1, 2010	Credit Valley Conservation
4	J.F. Sabourin & Ass.	2008		
6	ASCE	2000		
7	SWAMP	2002		
8	Dietz and Caausen	2005		
9	Hunt et al.	2006		
10	Davis	2007		
12	Hunt et al.	2008		
13	Roseen et al.	2009		
21	Deletic and Fletcher	2006		
23	U of Florida	2009	FDEP contract # WM 910	Dept. Env. Eng. Sciences, Gainesville FL
24	Wanielista et al.	1978	Shallow water roadside ditches for stormwater purification	www.stormwater.ucf.edu/FILES/wan1978paper.pdf
26	Harper, H.H.	1988	Effects of Stormwater Management Systems on Groundwater Quality	Florida Dept of Env Reg - project WM190
27	Dorman et al.	1989	Retention/Detention and overland flow for Pollutant removal from Highway stormwater runoff	Vol I research report. Federal Hwy Admin FJWA/RD-89/202pp
28	Yu, S.L. Et al.	1993	Testing of BMPs for controlling highway runoff	Virginia Transportation Research Council. FHWA/VA-93-R16.60pp
29	Goldberg, J.	1993	Dayton Ave Swale Biofiltration Study	Seattle Eng Dept - Seattle WA 67pp
30	Barrett et al.	1998	Performance of Vegetative Controls for Treating Highway Runoff	J. Environ Eng., 124(11) 1121-1128
31	Rushton et al.	2001	Florida Aquarium Parking Lot: A treatment train approach to SWM	SWFWMD, Brooksville, FL. Www.swfwmd.state.fl.us/ppr/reports/files/
32	Lloyd, S.D. Et al.	2001	Assessment of Pollutant Removal in a Newly constructed Bio-retention system	2nd South Pacific Stormwater Conference, Auckland, New Zealand
34	Lombardo &Line	2004	Evaluating the effectiveness of LID NCSU Water Quality Group	NC State U - conf proc: http://lowimpactdevelopment.org
35	Sharkey & Hunt	2005	Case Studies on the performance of Bioretention Areas in NC	8th biennial Stormwater research & wshed man conf www.swfwmd.state.fl.us/documents/
36	Birch et al.	2005	Efficiency of an Infiltration Basin in Removing Contaminants from Urban	Env. Mon. and Ass. 101: 23-38

Ref ID	Author	Year	Title	Publication
			Stormwater	
37	Davis et al.	2006	WQ improvement through Bioretention Media:N amd P removal	Water Environment Research 78(3):284-293
38	Brown & Hunt	2008	Bioretention performance in the upper coastal plain of NC	ASCE/EWRI World Environmental and Water Resources Congress
40	Osborn & Packman	2008	A comparison of conventional and low impact dev stormwater BMPs	ASCE/EWRI World Environmental and Water Resources Congress
41	Toronto and Region Conservation Authority	2010	Performance Evaluation of an Anionic Polymer for treatment of Construction Runoff	TRCA
42	Woodard and Rock	1995	Control of Residential Stormwater by Natural Buffer Strips	Lake &Reservoir Management 11(1), 37-45
104	Schueler, T.R.	2000	Comparative Pollutant Removal Capability of Stormwater Treatment Practices	Technical Note #95 from Watershed Protection Techniques. 2(4): 515-520.
105	Schueler, T.R.	2000	Pollutant Removal Dynamics of Three Wet ponds in Canada	Technical Note #114 from Watershed Protection Techniques. 3(3): 721-728.
106	Ministry of the Environment	2005	Synthesis of Monitoring Studies Conducted Under the Stormwater Assessment Monitoring and Performance Program	Prepared by the SWAMP program for GLSF, TRCA, MEAO and MOE, published by Toronto and Region Conservation Authority
109	http://www.bmpdatabase.org		The International Stormwater Best Management Practices (BMP) Database Project website	
111	Sansalone, J	2009	TARP Field Test Performance Evaluation of Sorbtive Filter using Sorbtive Media for Imbrium Systems Corporation	Dept. of Environmental Engineering Sciences at the Univ. of Florida. February 2009
112	Schueler and Holland	2000	The Practice of Watershed Protection	Centre for Watershed Protection, Ellicott City, MD

Ref ID	Author	Year	Title	Publication
113	Lee, C.R. and Skogergboe, J.G.	1985	Quantification of Erosion Control by Vegetation on Problem Soils	Soil Conservation Society of America, Arkeny, IA. pp.437-444
114	Taleban, V., Finney, K., Gharabaghi, B., McBean, E., Rudra, R. and Van Seters, T.	2009	Effectiveness of Compost Biofilters in Removal of Sediments from Construction Site Runoff	Water Quality Research Journal of Canada Vol. 44, No.1, 71-80

Appendix 8

Phosphorus Budget Tool in Support of Sustainable Development for the Lake Simcoe Watershed: Background on the Recommended Export Coefficients (MOE, draft report)

Appendix 9

Checklist of Required Elements for Review of Submissions

Checklist of Required Elements for Review of Submission

The following provides a checklist of elements that are required for the review of a phosphorus budget submission for a new major development. The checklist will be used by reviewers to ensure that the submission is complete and that the results of the phosphorus budget meet the requirements necessary for the Ministry to recommend approval of the development to the Municipality.

The MOE will recommend that municipalities approve development as site specific appropriate if:

a) Post-development load < or = pre-development load, and

b) (Post-development + amortized construction phase) load < or = pre-development loading,

OR

If (Post-development + amortized construction phase) load > pre-development loading,

THAT

All reasonable and feasible construction phase BMPs have been identified for implementation, documented and accounted for in the application.

The phosphorus budget submission requires the inclusion of the four page Summary Report produced by the Database Tool. In support of the information contained in the Summary Report, the submission should include:

Module 1

1. An orthographic aerial photograph that shows the delineation of pre-development land uses as per the EIS for the development that will be used to support the planning application to the Municipality.
2. Rationale to support the selection of land uses as defined in the Guidance Manual (Table 1) to most closely match those defined in the EIS land use mapping.
3. The correct database entry for the Lake Simcoe watershed in which the development is proposed. If the development area spans two or more subwatersheds, the submission should include a separate phosphorus budget for each area within each subwatershed.
4. Correct areas for each land use on the development site; the sum of which are equal to the total development site area.
5. The use of the pre-defined subwatershed and landuse specific export coefficients (in Table 2 of the Guidance Manual and coded in the Database Tool) for calculation of phosphorus loading from the pre-development site.

Module 2

1. An orthographic aerial photograph that shows the delineation of the post-development land uses as defined in Table 1 of the Guidance Manual.

2. Appropriate division of the site into post-development blocks that contain a unique combination of a land use and Best Management Practice or Treatment Train that will be applied to that land use in Module 3.
3. Correct areas for each post-development block; the sum of which are equal to the total development site area. The “Post-Development Area Altered” should equal the “Total Pre-Development Area” on page 2 of the Summary Report.
4. The use of the pre-defined subwatershed and landuse specific export coefficients (in Table 2 of the Guidance Manual and coded in the Database Tool) for calculation of phosphorus loading from the pre-development site.

Module 3

1. Specific references to the Stormwater Management Plan, where detailed descriptions and scientific rationales are provided for:
   a. The type of BMP or a Treatment Train approach that was chosen for each post-development block;
   b. The use of any phosphorus removal efficiencies for BMPs that are not pre-defined in the Tool;
   c. Each treatment in a Treatment Train, their respective phosphorus removal efficiencies and the total efficiency of the Treatment Train, if this option is to treat stormwater.

   If a custom BMP, phosphorus removal efficiency or a Treatment Train is used, this will be noted in red text on page 2 of the Summary Report.

Module 4

1. Appropriate division of the site into construction phase blocks, each of which comprise relatively uniform slope and soil characteristics and a unique capture BMP and prevention BMP combination.
2. Demonstrated, accurate input data for the soil loss calculations including:
   a. Area of each block;
   b. Predominant soil texture class and organic matter content;
   c. Surface slope gradient and length of slope;
   d. Duration of exposed soil for each block;
   e. Total duration of the construction phase.
3. Detailed descriptions and rationale for:
   a. Capture and prevention BMPs selected for each block;
   b. Use of any phosphorus removal efficiencies for BMPs that are not pre-defined in the Tool;

c. Each treatment in a Treatment Train, their respective phosphorus removal efficiencies and the total efficiency of the Treatment Train, if this option is to treat stormwater.

Final Summary and Analysis

If all elements above are contained in the submission and data are correctly entered in the database, the final summary (page 4 of the Summary Report) can be used as the final assessment of whether or not the results of the phosphorus budget meet the requirements necessary for the Ministry to recommend approval of the development to the Municipality.

If:

a) Post-development load < or = pre-development load, and

b) (Post-development + amortized construction phase) load < or = pre-development loading,

OR

If (Post-development + amortized construction phase) load > pre-development loading,

THAT

All reasonable and feasible construction phase BMPs have been identified for implementation, documented and accounted for in the application.

The final statement of page 4 of the Summary Report will display:

Based on a comparison of Pre-Development and Post-Development loads, the Ministry would encourage the Municipality to:

Approve development as site specific appropriate.

The above conclusion, however, assumes that the Ministry is in agreement with all rationales provided in the submission and are satisfied that “All reasonable and feasible construction phase BMPs have been identified for implementation, documented and accounted for in the application.”